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ORIGINAL ARTICLES.

I.—On the Stratigraphical Relations of the Dufton Shales and Keisley Limestone of the Cross Fell Inlier.

By J. E. Marr, Sc.D., F.R.S.

NOTWITHSTANDING all that has been written concerning the Keisley Limestone, its exact relations with the older Dufton Shales have never been clearly ascertained. I accordingly devoted a few days of the Easter vacation to the study of these relations in company with Messrs. W. G. Fearnsides, R. H. Rastall, and T. O. Bosworth, whose help I gratefully acknowledge.

For many years the Dufton and Keisley groups were referred to the 'Coniston Limestone,' and no attempt was made to separate them, although it was clear that the great differences existing between them required explanation. In a paper by the late Professor Nicholson and myself "On the Cross Fell Inlier"[1] we remarked of the Keisley Limestone, "the occurrence of some forms which have not been found nearer than the Chair of Kildare may indicate that we have here a fossil zone which is not represented by fossiliferous beds in the central part of the Lake District."

In a paper on "The Coniston Limestone Series"[2] I divided this series into three groups, namely, the Ashgill Group at the top, the Sleddale Group in the centre, and the Roman Fell Group at the base, placing the Keisley Limestone in the central and the *Staurocephalus* Limestone in the upper group. Furthermore, I stated (p. 101) that if the suggestion that the representative of the Keisley Limestone occurs at the top of the ordinary Sleddale Limestone in the main part of the Lake District be correct, "a further division of the Applethwaite Group may be made into a lower stage characterized by the ordinary Applethwaite fauna, and an upper stage characterized by the fauna of Keisley and the Chair of Kildare." This Applethwaite Group, it should be stated, is the upper division of the Sleddale Group.

[1] Quart. Journ. Geol. Soc., vol. xlvii, p. 511.
[2] Geol. Mag., Dec. III, Vol. IX, p. 97.

Our knowledge of the fauna of the Keisley Limestone was largely increased by the papers on that limestone written by Mr. F. R. Cowper Reed.[1] He there maintains that this fauna shows that the limestone must be removed from the Middle Bala and placed among the Upper Bala Beds—in other words, that it belongs to the Ashgill Group and not to the Sleddale Group. There is no doubt as to the correctness of this contention. Our recent observations show that the beds from which Professor Nicholson and I obtained our '*Staurocephalus* Limestone' fossils in the Cross Fell Inlier are *in* the Keisley Limestone and not *above* it. Mr. Reed found that the fauna possessed a strong affinity with that of the *Staurocephalus* Limestone, and we cannot now hesitate to refer the Keisley Limestone to the *Staurocephalus* Limestone.

The main results of our work at Easter were: (i) the discovery of the Keisley Limestone in Swindale Beck; (ii) the discovery of Dufton Beds in the Keisley Quarry; (iii) the detection of a low zone of Skelgill Beds above the Keisley Beds of the quarry. Attention may first be directed to our work in Swindale Beck.

In the section down this beck given in the plate appended to the paper "On the Cross Fell Inlier," the Dufton Shales are indicated as passing into the *Staurocephalus* Limestone and the latter into the Ashgill Shales. This is correct, but the existence of the Keisley Limestone here was not then suspected by us. Its non-detection is perhaps pardonable, for in summer the stream at this portion is so well-wooded that it is difficult to see the character of the beds in the dim light. At Easter, however, there is no such difficulty.

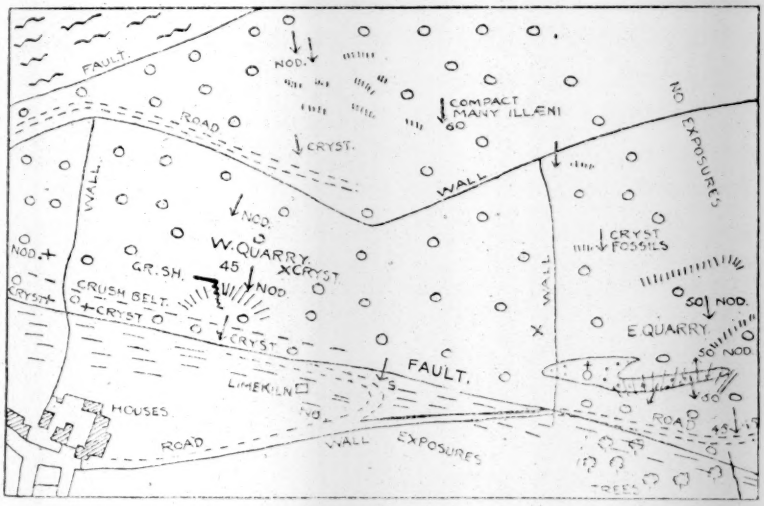
We stated that "at a point where a tributary stream (Rundale Beck) enters Swindale from the east the Dufton Shales are succeeded by a very calcareous deposit," which we refer to the *Staurocephalus* Limestone. The junction between the two is, indeed, close to this stream, but the highest beds of the Dufton Group occur on the south-west side of the stream and of a wall which bounds it. These beds consist of dark, almost black, limestone. Above them we measured approximately forty feet of grey compact limestone, of a nodular character, the nodules being most marked towards the base. This limestone exactly resembles that of the Keisley Quarries, where the latter has not become crystalline. In it, as stated above, are the more argillaceous beds, which furnished us with the fossils which we record as belonging to the *Staurocephalus* Limestone. The grey and nodular limestone is itself sparsely fossiliferous. We have found therein *Illænus* and one indeterminable *Trinucleus*. The occurrence of the latter is interesting, as it has not been found at Keisley. Notwithstanding its presence in Swindale, identity of lithological characters leaves no doubt that this Swindale Limestone is the Keisley Limestone. At the top it seems to pass perfectly conformably into undoubted Ashgill Shales, in which Mr. Fearnsides found *Phacops mucronatus*.

Professor Nicholson and I recorded the *Staurocephalus* Limestone in Billy's Beck. Here it is underlain by Dufton Shales (with

[1] Quart. Journ. Geol. Soc., vol. lii, p. 407, and liii, p. 67.

black limestones), the summit of which is not shown, and above it is a grey nodular limestone of the Keisley type, followed by a fault, on the other side of which the Browgill Shales occur. This section, therefore, also proves that the beds which we referred to the *Staurocephalus* Limestone are not above the Keisley Limestone.

We now pass on to the important sections of the hill behind Keisley hamlet. The accompanying plan, on the scale of 17½ inches to the mile, shows the distribution of the rocks. The two faults come together a little to the west of the plan, and no rock is seen in the portion between them in the triangular wedge not included in the plan.



Skelgill Beds.

Keisley Beds.

Dufton Beds.

Rhyolite.

s = position of fossils in Skelgill Beds.
CRYST = Crystalline Limestone.
NOD. = Nodular Limestone.
$\frac{s}{o}$ = position of fossils in Dufton Beds.

Arrows (→) represent the dips, and crosses (×) show where observations were made but no dips recorded.

FIG. 1.—Plan of part of the hill behind Keisley. Scale 17½ inches to a mile.

Two large quarries are now seen on the hill-side north of the hamlet, of which the more easterly is termed "Old Quarries" on the 25 inch Ordnance Map, while the westerly is simply marked "Quarry." I shall refer to these as the east and west quarries.

Beginning with the east quarry, we find an anticlinal fold exposed at its northern face, with black shales and limestones in the centre. At its western end these black limestones and shales are seen in a series of folds, as exhibited in the accompanying section, and their relationship to the Keisley Limestone clearly shown. It will be seen that, save for a wisp of shale, the highest bed of the dark series is a limestone. I have long known these beds, and believed them to belong to the Dufton Shales, and it is noteworthy that a calcareous band forms the summit here as in Swindale. All doubt as to the Dufton age of the beds has been set at rest by Mr. Fearnsides' discovery of fossils in some calcareous shales belonging to the group, in some excavations which he made on the hill-side about 20 yards west of the quarry at the point marked ♁ on the plan. The following is a list of fossils obtained from these excavations:—

Stromatoporoid?
Streptelasma? Common.
Heliolites tubulata, Lonsd. Common.
Heliolites sp. One specimen.
Dalmanella sp. Rare.
Orthis Actoniæ, Sow. Common.
Platystrophia biforata, Schloth. Common.
Triplesia spiriferoides, M'Coy.
Plectambonites sericea, Sow.
Trinucleus seticornis, His. Common.
Cybele verrucosa, Dalm. Common.
Calymene senaria, Conrad. Common.
Proetus cf. *ramisulcatus*, Niesk. One specimen.
Dalmanites sp. One specimen.

The fauna is clearly that of the Dufton Shales. The three common trilobites are those which are found in great abundance in the Dufton Shales of other exposures. Most of the other fossils have also been recorded from those shales, and those which have not are (with the exception of the *Dalmanites*, which is possibly new) found in the corresponding Sleddale Group of the Lake District. The supposed Stromatoporoid is clearly identical with a form recorded by Salter [1] from Coniston under the name of *Stromatopora striatella*, D'Orb.

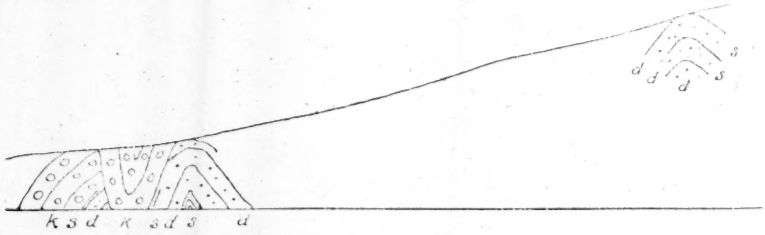


Fig. 2.—Section across west end of Dufton Inlier, showing folds.
Scale 1 inch = about 12 feet.

k. Nodular Keisley Limestone.
d. Limestones of Dufton Beds.
s. Shales of Dufton Beds.

We may now pass on to the consideration of the west quarry.

A crush belt with broken and silicified limestone crosses the floor of this quarry in a general W.N.W.–E.S.E. direction, with highly

[1] Cat. Camb. and Sil. Foss., p. 40.

crystalline limestone to the south of it at the west end of the quarry. To the north of this belt is the fine exposure of the northern face. The beds are dipping almost due south at an angle of 45°. They consist essentially of nodular grey limestone, which, however, is in places stained pink with hæmatite. Similar staining occurs in the limestone of many other parts of the hill. Where unstained, the limestone, as before stated, closely resembles the nodular limestone of Swindale Beck and Billy's Beck. Dipping with the limestone is an olive-green shale, which, however, is affected by many contortions, which cause it to undulate on the face of the quarry. It contains a number of nodes of limestone which will be further considered at a later stage, and is crushed to so great an extent as to break into papery sheets with very glossy surfaces. No fossils were seen in this, but a similar rock in a less crushed condition, occurring west of the wall which bounds the west end of the quarry, yielded some indeterminable fossils to Mr. Fearnsides' hammer. The rock there closely resembles the Swindale Beck rock to which Professor Nicholson and I originally restricted the term "*Staurocephalus* Limestone," and as the two occur in the Keisley Limestone they further increase the resemblance of the Swindale section to those of the Keisley Quarries.

Two or three years have elapsed since I detected graptolites of Skelgill Shale age in the road cutting east of the Old Limekiln and south-east of the west quarry (at S.). At Easter Mr. Fearnsides obtained a number of graptolites from this locality, and was able to prove that the zone was that of *Dimorphograptus confertus*. The beds are dipping a little west of south. As there is not enough room for the Ashgill Shales between this exposure and the nearest outcrop of Keisley Limestone, there is undoubtedly a fault separating the Skelgill Beds and the Keisley Limestone.

So far as the relations of the Keisley Limestone to other strata are concerned, our observations show: (i) that the highest beds of the Dufton Series are marked by calcareous black limestone with subordinate shales, the limestones containing few fossils save crinoids; further, that these calcareous beds occur in the Keisley section and in that of Swindale; (ii) that the change from the dark Dufton Beds to the lighter-coloured Keisley strata is abrupt, but there does not appear to be any unconformity; (iii) that the Keisley Beds consist mainly of fairly pure limestone, but that more argillaceous beds are interstratified with the purer limestone; from these more argillaceous beds Professor Nicholson and I extracted the fauna of our *Staurocephalus* Limestone; (iv) that the Keisley Beds of Swindale appear to be succeeded conformably by the Ashgill Shales.

I now turn to a consideration of the peculiar development of the Keisley Limestone in the Keisley exposures. I have elsewhere argued that it is a 'knoll' of limestone which has been thickened by folding and taken on peculiar structure during that folding, and recent examination tends to confirm this view.

The section figured shows that folding on a considerable scale has affected the rocks of the east quarry, and abundant minor folds are proved to exist in the west quarry by the puckering of the shales.

In the east quarry the Keisley Beds of nodular type are dipping southward from the Dufton Beds, to pass below the Skelgill Beds. Some of the upper beds of the Keisley Limestone may be faulted out here, but the beds which actually exist are not more than forty feet thick, and therefore no thicker than the beds of this age in Swindale, where they appear to present a normal sequence. To the north of the anticline which brings up the Dufton Beds, the Keisley Beds dip nearly due north for a very little way, and still further north there is a continuous southerly dip at angles varying from 60° to 75° for a distance of about 200 yards. Unless a fault exists along the line where the dip in the Keisley Beds changes from north to south, the Dufton Beds should come to the surface at no great distance to the north of the change of dip. There is no sign of any such fault, and the alternative explanation is that the Keisley Limestone is here folded into a series of isoclines, with the Dufton Beds concealed beneath at no great distance below the surface.

It is well known that the bulk of the Keisley fossils have been obtained from a highly crystalline whitish limestone, though here and there they occur in compact limestone, as in the case of the abundant *Illæni* in a horny limestone whose position is marked on the plan. One would naturally expect that the crystalline and compact limestone belonged to different beds, and at the outset we attempted to prove that the crystalline limestones were above the nodular and compact limestones. A further examination proved that they were quite irregularly distributed, as shown on the plan, where the principal exposures are indicated, the crystalline limestones being marked 'cryst.' and the compact nodular limestones 'nod.' Further search proved that this irregular distribution was traceable on a very small scale, so that at times a hand-specimen could be obtained with one portion compact and the other crystalline, the two being separated by very irregular junctions, with no traces of bedding-planes. It seems impossible to escape the conclusion that the compact limestone was the original rock, and that crystallisation, as the result of subsequent change, has affected it sporadically in this Keisley tract, where there is clear proof of much thickening by folding, whereas in the Swindale section, where there is no evidence of thickening, the crystalline variety is absent.

It is interesting to note that little knolls of crystalline limestone occur in profusion in the shale-band of the lower part of the northern face of the west quarry, in a way which recalls similar little knolls which I elsewhere described in the shales associated with the limestone of the Draughton Quarry of the West Riding of Yorkshire.[1]

The question arises, why should the limestone be thickened and crystallised at this point and not in Swindale? In connection with this I would point out that elsewhere the Dufton Shales show evidence of much repetition, and the limestone may have resisted folding when sandwiched between the soft Dufton Shales below and the Ashgill and Skelgill Shales above. Here the Dufton Shales are

[1] "On Limestone Knolls in the Craven District of Yorkshire and elsewhere": Quart. Journ. Geol. Soc., 1899, vol. lv, pp. 336–338.

faulted out to the north of the mass, so that the Keisley Beds come into contact with the rhyolite of Keisley Bank. There is little shale above, and the massive Browgill Shales soon succeed the thin Skelgill Beds. During the movements, owing to the absence of the Dufton Shales by faulting on the north, the Keisley Beds and the calcareous top of the Dufton Shales would be pressed against the hard rhyolite, and would in all probability tend to fold against it.

Whatever be the origin of the structure of parts of the Keisley Limestone, the exact position of that limestone in the stratigraphical succession must be regarded as definitely established. The limestone and the more argillaceous beds intercalated with it belong to the *Staurocephalus* Limestone group, and occur between the Dufton Shales and the Ashgill Shales.

II.—Notice of some Fossils from Singapore discovered by John B. Scrivenor, F.G.S., Geologist to the Federated Malay States.

By R. Bullen Newton, F.G.S.,
of the Department of Geology, British Museum (Nat. Hist.), Cromwell Road, S.W.

(PLATE XXV.)

Introduction.

As representing the first fossils yet recorded from Singapore, these specimens are of considerable interest. They principally consist of marine Lamellibranch remains accompanied by an obscure indeterminable Gasteropod, and a few fragmentary terrestrial plants. Their condition, however, as casts and impressions renders them most difficult to work out satisfactorily, more especially the shells where only external features of the valves are available for study. Some of the specimens, however, retain certain points of structure or contour which appear to have an important bearing on their probable geological age. The association of land and marine organisms would at once suggest an estuarine or lagoon origin for the beds containing them, more especially as the mollusca belong to genera or families which may be regarded as of shallow-water habit, whilst the plant-remains might be accounted for by the close proximity of land or the transporting agency of river action. Among the shells, that referred to *Goniomya* is of chief interest, since it belongs almost exclusively to the Mesozoic period, being particularly characteristic of Jurassic rocks and of much rarer occurrence in deposits of Cretaceous age.

Although exceedingly rare, *Goniomya* has also been found in Palæozoic rocks, Krotow having figured and described *G. Artiensis* from the Russian Permian (Soc. of Naturalists Imp. University of Kasan, 1885, vol. xiii, p. 225, pl. iii, fig. 20), and an unnamed form from rocks of similar age in the Central Himalayas has been more recently recorded by Dr. Carl Diener (Palæontologia Indica,

1903, ser. xv, vol. i, pt. 5, p. 126, pl. v, fig. 19, and p. 176, pl. viii, fig. 11).

The plant structures, although obscure, are also important. A leaf-like body has been referred to *Podozamites* cf. *lanceolatus* (Lindley & Hutton), a genus and species which enjoyed an extensive geographical distribution during the Bajocian stage of Jurassic times, having been recorded from Yorkshire (Haiburn Wyke); Spitzbergen; Orenburg; East Siberia; Astrabad, Persia; India (Upper Gondwana Beds); China; Japan; and Korea.

Podozamites is but one member of a large group of similar plants, generally included under the Cycadaceæ, which were of abundant occurrence in the Mesozoic period, and of which *Williamsonia* may be regarded as the type. Such a flora has been described by Feistmantel as typical of the Upper Gondwana deposits of India, and it is of further interest to note that marine molluscan remains have been also found in some of those beds associated with the plants (R. D. Oldham's edition of Medlicott & Blanford's "A Manual of the Geology of India," 1893, p. 180).

The Singapore Clays, therefore, with their estuarine contents, may be of Middle Jurassic age, and about the horizon of the Inferior Oolite of England or the so-called Bajocian of Continental geologists. They possibly represent an extension or outlier of the Upper Gondwana rocks of India, as well as forming part of the other fossiliferous areas of Eastern Asia, including Korea, Japan, and Siberia, which have yielded a similar vegetation.

Mr. John B. Scrivenor, the discoverer of these fossils, has furnished the following account of the beds and locality, stating that the specimens were obtained "from a 2 ft. (*circâ*) bed of silty clay with obscure plant-remains, forming a part of the series of shale and sandstone beds which embraces all the known sedimentary rocks of Singapore Island apart from surface deposits, and exposed in a big quarry on the north flank of Mount Guthrie, Tanjong Pagar, Singapore Town.

"What remains of Mount Guthrie is likely to disappear before long; in fact, the original hill extended over the spot where I found the fossils. The specimens take some time to collect, as they are sparsely distributed. I send the best fossil leaf I could find and also an object which may be a fruit. I also saw obscure vegetable remains in shale at Tanjong Malang, close by; and at Mount Wallich, also close by, I saw one piece of badly-preserved fossil wood. In the Mount Guthrie quarry, about 50 yards from the fossiliferous horizon, I found a 6 inch seam of very poor brown coal.

"The shale and sandstone series is very highly inclined in this part of Singapore; in one section I saw the beds are vertical. At Mount Guthrie the strike is N.N.W.–S.S.E., the dip about 75° W.S.W.

"The strike and petrological characteristics of the series wherever seen suggest a connection with the shale and sandstone of the Federated Malay States; but, again, were these rocks situated in Sarawak [Borneo] the petrological evidence and the presence of the obscure vegetable remains would not be sufficient alone to separate

them from the shale and sandstone of Upper Sarawak and Santubong" [Borneo].[1]

Description of the Fossils.

The matrix containing the fossils is a light drab-coloured compact clay, varying slightly in tint and particularly soft to the touch, marking everything as if it were chalk, although according to the acid test no calcareous constituents are present. Dr. G. T. Prior, of the British Museum, who has examined the material, has detected some minute particles of silica entering into its structure.

The specimens herewith described and figured have been mainly collected by Mr. John B. Scrivenor, although a second series from the same locality and beds was subsequently furnished to the writer by Dr. R. Hanitsch, of the Raffles Museum, Singapore, three of which are represented on the Plate by Figs. 3, 4, and 17. Through the good services of both Mr. Scrivenor and Dr. Hanitsch the specimens selected for illustration have been presented to the British Museum. A word of praise should be extended to the artist, Mr. A. H. Searle, for the excellent drawings he has constructed from obscure and difficult material, and which, thanks to the collotype process, have been satisfactorily reproduced on the Plate.

LAMELLIBRANCHIA.

Cucullæa Scrivenori, sp. nov. (Pl. XXV, Fig. 13.)

Shell small, compressed, inæquilateral, subquadrate, oblique; umbo very anterior; dorsal margin horizontal, short; anterior area short, deep, obliquely and roundly truncated; posterior region wide, produced, rounded, and bearing an elongate oblique depression, with an angulation at the posterior end of the hinge-line; ventral margin nearly parallel with dorsal line; ornamentation consisting of extremely fine concentric growth-lines crossed by a series of delicate radial striations.

Dimensions.—Length 13, height 7 mm.

The specimen referred to this form is a small, rather compressed right valve, embedded in the rock, and, like the other specimens from this locality, only showing external characters. It appears to differ from previously described forms of this genus by its very inæquilateral character, the umbo being within a small distance of the anterior margin, and the relatively long and narrow posterior depression. The sculpture markings are obscure, but when properly shaded the valve shows decussating striations.

Collector.—Mr. J. B. Scrivenor.

[1] These Borneo Beds have been examined and reported upon by Mr. John B. Scrivenor, and the results issued in a Government paper (No. 8) published at Kuala Lumpur by the Geological Department of the Federated Malay States on the 19th January, 1905, entitled "A Report on the Geology of the Residency of Sarawak, and of the Sadong District, Borneo, with special reference to the occurrence of Gold and Coal."

ARCA sp. (Pl. XXV, Fig. 14.)

Shell narrow, elongate; hinge-line horizontal and parallel with ventral border; umbo depressed, anterior, oblique; carinated obliquely and obtusely from umbonal region to postero-ventral margin; anterior end rounded, posterior truncated, and area depressed; sculpture consisting of very obscure concentric lineations without evidence of radial striæ.

Dimensions.—Length 20, height 8 mm.

This description applies to a natural cast of a right valve embedded in the rock showing the external surface. Narrow forms of *Arca* are fairly common in Jurassic deposits, but they are invariably ornamented with radial striation; as no such sculpture exists in the Singapore fossil it may be inferred that none was ever present, although it is possible that the counterpart, which does not appear to have been preserved, might have yielded a better interpretation of the original surface structure.

Collector.—Mr. J. B. Scrivenor.

GERVILLIA HANITSCHI, sp. nov. (Pl. XXV, Fig. 4.)

Shell lanceolate, subcylindrical, curved at ventral margin, moderately convex at carina; anterior area, shortest, with an acute cuneiform termination, narrow and produced posteriorly; umbonal region terminal; dorsal area, constituting a long narrow obliquely striated depression, entirely bordered within by an obtuse carina, and above by an obscure lengthened hinge-line; growth-lines slightly impressed.

Dimensions.—Length 54, height 12 mm.

This interesting specimen consists of a natural cast and counterpart, showing external surface of a left valve, which resembles in many of its characters some Jurassic forms of the genus, such as *G. monotis*, Deslongchamps, from the Bathonian of Britain and Europe, or *G. acuta*, J. de C. Sowerby, of Bajocian age. From the former it appears to differ in its lesser convexity and longer hinge-line, and from the latter in its less oblique and more lengthy hinge area.

Collector.—Dr. Hanitsch.

VOLSELLA cf. COMPRESSA, Goldfuss. (Pl. XXV, Fig. 5.)

Mytilus compressus, Goldfuss: Petrefacta Germaniæ, 1837, vol. ii, pl. cxxxi, fig. 11, p. 178. Morris & Lycett: Mon. Pal. Soc. (Great Oolite Mollusca, part 2), 1853, pl. iv, fig. 7, p. 40.

In general contour and flatness this shell is closely related to *Mytilus compressus* of Goldfuss, originally described from Hanover and the Stonesfield Slate. The principal distinction appears to be in the concentric lineations, which are fewer and more distant in the Singapore fossils, although some obscure ones are traceable between the more important striæ, especially on the lateral areas. The umbo is not terminal as in *Mytilus*, so that this form is recognized as a true *Volsella* (= *Modiola*). The specimen shows an external view of a left valve embedded in matrix.

Dimensions.—Length 20, height (maximum) 10 mm.

Collector.—Mr. J. B. Scrivenor.

? NUCULANA sp. (Pl. XXV, Fig. 7.)

A figure has been drawn of a fragmentary valve which may represent either a *Nuculana* or an *Anatina*, that is if the shell can be assumed to have possessed a rostration as indicated by the dotted lines. The specimen shows an external view of a compressed right valve with a short and rounded anterior area and a horizontal dorsal line which forms the boundary to an obtusely angled, elongate area, extending posteriorly from the rather flattened umbonal region. The surface of the valve is delicately striated concentrically, and slightly wrinkled posteriorly.

Supposing the specimen originally to have been rostrated, then the concentric lineation is finer than usually obtains in *Anatina*, being perhaps more applicable to *Nuculana*, although even in that genus the dorsal line appears to be too horizontal, an obliquity being usually apparent descending from the umbo before proceeding in the posterior direction.

Collector.—Mr. J. B. Scrivenor.

? NUCULOID SHELL. (Pl. XXV, Fig. 6.)

The "Nuculoid shell" here referred to is an external view of a narrow, lanceolate right valve, buried in the matrix, and preserved as a natural cast together with the counterpart. The umbo is very anterior, small, and scarcely rising above the hinge-line; the dorsal and ventral margins are subparallel; anterior margin short and rounded; posterior oblique, produced, and subacuminate; sculpture consisting of delicate striæ of growth, concentrically arranged; no crenulations observable on the hinge area.

Dimensions.—Length 20, height 8 mm.

It is not possible to determine more closely the shell which is here figured and briefly described. Probably it is a form related to *Nucula*, but the absence of crenulations at the hinge area renders such a supposition very doubtful. Further, there is a resemblance in general contour to Conrad's Palæozoic genus *Nuculites*, the casts of which in common with the specimen from Singapore bears a narrow notch-like cavity in the anterior region beneath the umbo; but, again, the want of cardinal crenulations would create a difficulty if included in such a genus. With better material at some future time this shell may eventually be identified.

Collector.—Mr. J. B. Scrivenor.

? LUCINA sp. (Pl. XXV, Fig. 15.)

The specimen referred doubtfully to the genus *Lucina* is a small, subcircular, rather compressed, right valve, showing a nearly mesial rounded umbo directed obliquely forward, and having its surface ornamented with numerous, closely-set, microscopical, concentric striations, which are more obvious on the ventral and lateral areas than on the umbonal region. In the postero-ventral direction the valve is imperfect; this has been indicated in the figure by a dotted line. It is impossible to suggest to what shell this fragmentary valve might be related, although interesting for

reference as one of the species found in the Singapore Clays. This specimen may be also said to resemble some small forms of *Unicardium*.

Dimensions.—Length 11, height 10 mm.

Collector.—Mr. J. B. Scrivenor.

Astarte Scrivenori, sp. nov. (Pl. XXV, Figs. 11, 12.)

Shell subquadrate, slightly convex; umbo anterior; dorsal line slightly oblique; posterior area depressed, sloping, and angulated below; ventral margin nearly parallel with dorsal; anterior area rounded and short. Ornament consisting of from 10–12 nearly horizontal costal ribs, obtusely angled on both sides, and separated by rather wide sulcations; anterior costæ crowded and finest in front.

Dimensions.—Fig. 11, length 14, height 11 mm.; Fig. 12, length 11, height 7 mm.

This form is represented by two right valves of different ages, the younger showing a much finer and more crowded system of costæ (Fig. 12), whilst the older shell (Fig. 11) possesses a bolder and coarser sculpture. The lateral angles of the costæ present a feature of interest in the sculpture which is apparently not known among typical astartiform shells, hence it has been regarded as a new species. In addition it may be mentioned that this species shows a certain resemblance in contour and structure to *A. interlineata* of Lycett, from the Great Oolite of Minchinhampton (see Mon. Pal. Soc., 1854, pl. ix, figs. 14, 15, p. 87).

Collector.—Mr. J. B. Scrivenor.

Astarte Guthriensis, sp. nov. (Pl. XXV, Fig. 9.)

Shell small, subelliptical, moderately convex; umbo anterior; front area short, rounded, slightly excavated beneath the umbo; posterior margin elongate, oblique; ventral border thickened, rounded; sculpture consisting of about 10 wide, elevated, concentric costæ, bearing minute lineations, divided by smooth sulcations of nearly equal width.

Dimensions.—Length 11, height 6 mm.

This specimen is embedded in the matrix and exhibits an external view of the right valve. The dorso-posterior margin is rather imperfect, otherwise the specimen is fairly seen and its ornamentation is well displayed. The raised concentric and striated ridges divided by the prominent smooth sulcations and without any evidence of radial lines, are the chief sculpture characters of the valve.

Collector.—Mr. J. B. Scrivenor.

Astarte Guthriensis, var. nov. (Pl. XXV, Fig. 10.)

Shell with similar sculpture to *A. Guthriensis*, but of rather quadrate form, and considerably less oblique posteriorly.

Dimensions.—Length 10, height 7 mm.

This variety is represented by an external surface of a right valve in which the umbo is not preserved, but the excavation beneath is well marked.

Collector.—Mr. J. B. Scrivenor.

Goniomya Scrivenori, sp. nov. (Pl. XXV, Fig. 1.)

Shell narrow, convex, subcylindrical, umbo anterior, vertical, and not prominent; dorsal margin gently sloping from umbo on each side, anterior end rounded, posterior truncated; sculpture consisting of a regular series of about 16 V-shaped, slightly curved, oblique costæ, which are elevated, rounded, funiculate, and divided by prominent sulcations, bearing closely-set, obscure, longitudinal striations; some of the costæ at the anterior end are angulated inwards.

Dimensions.—Length 21, height 7 mm.

This specimen, represented by an external view of a left valve embedded in the clay-matrix, is beautifully marked, the costæ showing a delicate cord-like structure; it is of narrowly elongate form, and appears to differ from all other members of the genus by its non-prominent umbo, the presence of angulate costæ at its anterior end, and the funiculate ornamentation of the costal ribs. The limits of the ventral margin are not defined.

Collector.—Mr. J. B. Scrivenor.

Goniomya Singaporensis, sp. nov. (Pl. XXV, Figs. 2, 3.)

Shell elongate, slightly convex; umbonal region very anterior, obtuse, vertical, slightly elevated at summit; posterior dorsal margin oblique, long; anterior area obliquely margined from the summit, short, rounded; sculpture consisting of a series of V-shaped, sharply angulated costal ribs arranged beneath the umbonal area, separated by sulcations, which are finer and closer on the anterior side and wider apart and divided by broader grooves posteriorly; the ribs are elevated, rounded, and slightly curved outwards; surface of grooves bearing fine longitudinal striations with obscure indications of striæ on the anterior costæ.

Dimensions.—Length 32, height (from umbo to thirteenth angulation) 11 mm.

Two out of the three specimens representing this form are shown in Figs. 2 and 3, the former, an excavated impression of a right valve, being the most perfect, though deficient in ventral details; whilst Fig. 3 applies to a fragmentary natural cast of a left valve in which the angulated costæ and the short anterior region are well displayed.

This species differs from *G. Scrivenori* in its more anterior umbo, its much shorter anterior area, more oblique posterior margin, and its less defined ornamentation. It was probably a cylindrical form resembling such a species as Agassiz's *Goniomya sulcata* from the Jurassic rocks of Switzerland, which also possesses very anterior umbones, but differs in having coarser ribbing and a more prominent umbonal area, which is inclined to obliquity. In the absence of dental characters it is impossible to say whether the Singapore specimens might not belong to *Trigonia*, as some forms of that genus exhibit a V-shaped ribbing, such as have been described by Dr. Kitchen from the Oomia Beds (Upper Jurassic) of India (Palæontologia Indica, 1903, ser. ix, vol. iii, p. 70, pls. vii, viii), but

the finer and more regular ornamentation would in any case at once distinguish them from the Indian shells.

Collectors.—Mr. J. B. Scrivenor (Fig. 2) and Dr. Hanitsch (Fig. 3).

? Thracia sp. (Pl. XXV, Fig. 8.)

I have placed doubtfully under the genus *Thracia* the largest of the shell remains found in the Singapore deposits. Unfortunately the umbo is wanting, and its exact position is very uncertain, although it was possibly more or less mesial. The specimen consists of a considerably fractured natural cast representation of the left valve of an elongate shell, rounded anteriorly, with a probably nearly horizontal dorsal margin, and possibly an elliptically curved base. It has the appearance of having had originally an oval outline, and in the posterior region, where the principal characters are merged, there is an obtusely angulated area descending obliquely from the umbonal region to the median angulation of the truncated margin, producing a cuneiformity of outline which is repeated within by the concentric growth-lines.

Dimensions.—Length 62, height (about) 33 mm.

Collector.—Mr. J. B. Scrivenor.

PLANTÆ.

Podozamites cf. lanceolatus, Lindley & Hutton. (Pl. XXV, Figs. 16, 17.)

Zamia lanceolata, Lindley & Hutton: Fossil Flora Great Britain, 1836, vol. iii, pl. 194.

Podozamites lanceolatus, Seward: Catalogue Mesozoic Plants British Museum, The Jurassic Flora (Yorkshire Coast), 1900, p. 242, text-figure No. 44 on p. 245. H. Yabe: Journ. Coll. Sci. Imp. Univ. Tōkyō, Japan, 1905, vol. xx, Article 8, pl. iv, figs. 1–5, p. 17.

The largest of the two specimens appearing to bear a relationship to *Podozamites lanceolatus* consists of a long leaf-like body embedded in the clay-matrix, much crushed and bent about at its widest end, and diminishing rather rapidly at its other extremity for probable attachment to a rachis, whilst a series of parallel lines or venations traverses the entire surface of the organism. There is no indication of a stem, although the peculiar narrowing of the supposed basal end would suggest that that part would form the point of attachment. The broader end is not complete, so that the original length is uncertain, but the maximum width of the pinna can be given as 16 mm. Although much broader than the pinnæ of typical examples, this specimen is by no means the widest known, Dr. Yabe having recently figured some specimens from Korea with a measurement of 20 mm.

The second specimen represents another fragmentary pinna, which is of smaller dimensions, being only 7 mm. wide. It is, however, of interest, since a well-rounded, slightly notched, basal margin can be seen, as well as the characteristic parallel venations, the more lateral of which curve slightly inwards at the termination. Unfortunately the apical region is incomplete, and there is no means of

ascertaining the exact length of the fossil, although it is probable that it was a much shorter form, such as has been figured by Dr. Yabe from Korea and compared with *P. pulchellus* of Heer from Spitzbergen (Kongl. Svensk. Vetensk.-Akad. Handl. [Stockholm], 1876, vol. xiv, No. 5, p. 38, pl. ix, figs. 10–14). A slight resemblance can also be traced to a pinna recently figured by Mr. Seward from the Stonesfield Slate as *P. Stonesfieldensis* (Catalogue Mesozoic Plants British Museum, Liassic and Oolitic Floras of England, 1904, pl. iii, fig. 4, p. 123), in which a basal notch has been likewise observed.

Remains of this plant are frequently found in a poor state of preservation, and only detached pinnæ as a rule are obtained, these being sometimes damaged at their terminations like the Singapore specimens. The species is a very variable one, the pinnæ differing considerably in dimensions and the number of parallel venations never being quite the same. Its geographical distribution is extensive. Originally described from the Yorkshire Oolites, it has since been recorded from European countries, Spitzbergen, Siberia, Persia, India (Upper Gondwana Beds), China, Japan, and Korea. For an exhaustive synonymy of the species Mr. Seward's British Museum Catalogue should be consulted.

Collectors.—Mr. J. B. Scrivenor (Fig. 16) and Dr. Hanitsch (Fig. 17).

Carpolithes sp. (Pl. XXV, Fig. 18.)

An isolated seed, buried in the matrix, of apparently a Cycadean character has been provisionally referred to the genus *Carpolithes*. It is of rather oblong contour with nearly parallel sides, and bearing a longitudinal rounded ridge on the right margin, which may represent a fractured edge of the outer cuticle of the seed. The central oval and convex body, which is possibly the naked seed itself, is minutely and concentrically striated, especially on the sides.

In connection with the remains of *Podozamites* it is interesting to find a seed of this character in association, as the assemblage is suggestive of a Lower Oolite flora, such as characterise the rocks of the Yorkshire coast, Stonesfield, and the more distant Jurassic regions.

Dimensions.—Width 7, height 8 mm.

Collector.—Mr. J. B. Scrivenor.

EXPLANATION OF PLATE XXV.

Fig.

1. *Goniomya Scrivenori*, sp. nov. External view of a left valve. × 2.
2. *G. Singaporensis*, sp. nov. External view of a right valve drawn from a wax cast of original impression. Nat. size.
3. *G. Singaporensis*. External aspect of a fragmentary left valve. Nat. size.
4. *Gervillia Hanitschi*, sp. nov. External view of natural cast of a left valve. Nat. size.
5. *Volsella* cf. *compressa*, Goldfuss. External view of a left valve. × 2.
6. [? Nuculoid shell.] External view of a right valve, showing obscure anterior notch. Nat. size.
7. ? *Nuculana* sp. External view of a right valve, the dotted line showing probable rostration. Nat. size.

Fig.
8. ? *Thracia* sp. Natural cast of an imperfect left valve showing external features. Nat. size.
9. *Astarte Guthriensis*, sp. nov. External view of right valve. × 2.
10. *A. Guthriensis*, var. Outer view of a right valve. × 2.
11, 12. *A. Scrivenori*, sp. nov. External views of right valves. Fig. 12 drawn from a wax cast of original cavity. Nat. size.
13. *Cucullæa Scrivenori*, sp. nov. External view of right valve. × 2.
14. *Arca* sp. External view of a natural cast of a right valve. Nat. size.
15. ? *Lucina* sp. Outer aspect of a fragmentary right valve. × 2.
16. *Podozamites* cf. *lanceolatus*. An incomplete pinna showing the probable base as tapering to a point where attachment to the rachis might have been effected. Nat. size.
17. *Podozamites* cf. *lanceolatus*. A more imperfect fragment of another pinna with an obscure indication of a basal notch. × 2.
18. *Carpolithes* sp. Longitudinal view of a seed showing on the right margin the remains of a possible outer integument. × 2.

Note.—Specimens represented by Figs. 3, 4, and 17 were collected and presented to the British Museum by Dr. R. Hanitsch; the remainder were collected by Mr. J. B. Scrivenor and similarly presented by him to the same institution.

III.—The Carboniferous Succession below the Coal-Measures in North Shropshire, Denbighshire, and Flintshire.

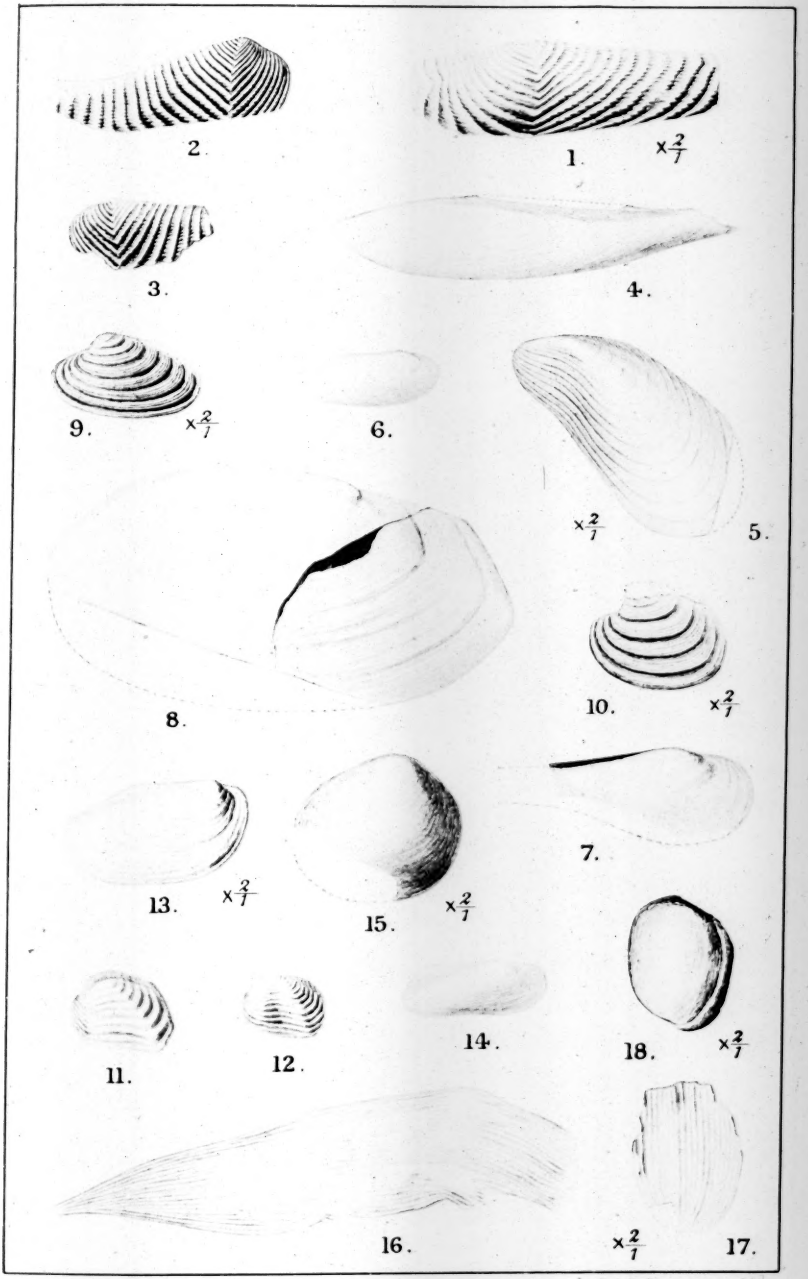
By Wheelton Hind, M.D., B.S., F.R.C.S., F.G.S., and John T. Stobbs, F.G.S.

(*Concluded from the October Number, p.* 459.)

5. Comparison of the Palæontological Sequence of the Carboniferous Rocks of North Wales with that which occurs in other Carboniferous Areas in England and Wales.

The palæontological succession of the Carboniferous rocks of North Wales is practically identical with the succession in the Pennine area, and to a certain extent with that which obtains in the Bristol–Mendip area.

Dr. A. Vaughan has demonstrated that in the latter district the distribution of the Corals and Brachiopoda affords a definite basis for the subdivision of the Carboniferous Limestone into life-zones (Quart. Journ. Geol. Soc., vol. lxi, pp. 180–307). We have found the corals most valuable indices during our work in North Wales. Apparently the vertical distribution of the Carboniferous corals demonstrates a progressive evolution, and both genera and species have a definite vertical range and are therefore time indices. They can on that account be safely relied upon for the correlation of beds in faulted or widely separated areas. With regard to the Brachiopoda, here again within limits certain definite mutations of a form, which evidently have a certain genetic relationship, appear only at particular horizons and have a definite vertical range. Unfortunately many of the names of the Brachiopods selected by Dr. Vaughan as the zonal indices belong to species which were founded on specimens which occurred at much higher horizons than those to which he would have referred them in the Bristol area. They are therefore the last mutation of the genus of the peculiar species rather than one of



A. H. Searle, del.

Mesozoic Fossils from Singapore.

the earlier mutations. The specific names must be strictly kept for the special form occurring in the beds whence the type-specimens were derived. We instance, more particularly, *Schizophoria resupinata*, Martin, *Syringothyris cuspidata*, Martin, *Spiriferina octoplicata*, Sow., the types of which came from beds in Derbyshire which belong to the higher coral zones. It will be a very easy matter to indicate in some simple way or other the precise mutation which is typical of the lower beds without introducing any ambiguity.

With regard to our researches in the Carboniferous rocks of North Wales, certain very definite results obtain. We find that there is no evidence that any beds belonging to the series which come on below the *Dibunophyllum* zones in the Bristol–Mendip area are represented in North Wales, except possibly some few feet of the Upper *Seminula* beds.

The Basal Conglomerate, containing derived fossils only, which lies between the Silurian rocks and Carboniferous Limestones in some localities, is unconformable to the Lower rocks, but conformable to the limestones. Although red in colour it therefore represents a time late in the Carboniferous period, judged from the Bristol–Mendip succession, and consequently is in no way the homotaxial equivalent of the Old Red Sandstone.

The Conglomerate is due to purely physiographical conditions, and represents the initial deposits laid down upon a sinking land surface, a fact indicated by the petrological study of the pebbles which enter into its composition (Strahan & Walker, Quart. Journ. Geol. Soc., vol. xxxv, pp. 268–274). These conglomerates appear locally on the western side of the Vale of Clwyd, and the thickest section appears to be at Ffernant Dingle, where a fairly complete succession can be made out. At other places, as at Minera quarries, the Carboniferous Limestone rests unconformably but immediately on beds of Bala age. At Llangollen Mr. Morton estimated that the beds which he then called Old Red Sandstone, were 50 feet thick.

Comparative sections of the Carboniferous Limestone show that this series thins out rapidly from north to south, and while the upper beds can be traced across the whole district by their zone fossils, the lower beds are wanting in the south. This must have been due to the fact that the southern part of the sinking land surface was higher than that to the north, and consequently only received the deposit later on. Hence it follows that the base of the Carboniferous Limestone in North Wales does not represent the same horizon in every locality, and further that the Basal Conglomerates, where present, are not necessarily all of the same age in point of time, owing to the fact that deposition took place on an uneven and irregular floor.

It is questionable whether the *Seminula* zone of the Bristol area is represented at all in North Wales. It is true that the zone fossil, *Seminula ficoides*, Vaughan, is fairly abundant south of Dyserth, between Pentre-bach and Pentre Cwm (mentioned in the Memoir of the Geological Survey, "The Geology of the Coasts adjoining

Rhyl, Abergele, and Colwyn," p. 9), where it occurs with *Archæosigillaria Vanuxemi*, Göpp., and other plant-remains. This shell was evidently alluded to as *Athyris Royssii* in the memoir.

The absence of *Caninia* makes it definite that only the top of the *Seminula* beds, if any, can be present. In the Bristol area *Seminula* is still present in the Lower *Dibunophyllum* zone. It is therefore certain that the lowest limestones of the North Wales sequence cannot be lower than the junction of the *Seminula* and *Dibunophyllum* zones of Bristol.

In North Wales *Daviesiella* (*Productus*) *Llangollensis* characterises the lowest beds of limestone at Llangollen and Minera, but it is found some little distance above the base, and associated with *Seminula* at Llandulas. The internal characters of *Daviesiella* (*P.*) *Llangollensis* closely resemble those of *Chonetes* aff. *comoides*, Vaughan, which that writer proposes to call *Choneti-productus*. It is important to note that the one species in North Wales and the other in Bristol occur apparently at the same level, i.e. practically at the junction of the Upper *Seminula* and Lower *Dibunophyllum* zones.

Hence we arrive at the important conclusion that the whole of the Tournaisian Series as represented in the Bristol area, and nearly all, if not all, of the *Seminula* beds, were not deposited in North Wales, and we may reasonably infer that this area was not submerged during the time that these beds were being laid down in the south-west of England. This fact is of great importance, and clears away many of the great difficulties that the distribution of the Carboniferous corals in the Pennine area and the Lower Limestone Series of Scotland apparently opposed at first to Dr. Vaughan's conclusions. It was a well-known fact that the more highly evolved corals, the Dibunophyllids, Clisiophyllids, and *Lonsdaleia*, in fact the upper coral fauna, were found at the base of the Carboniferous Limestone, Westmoreland (Shap) and in the Lower Limestone Series of Scotland. It was also puzzling why the lower faunas of the Bristol area had not been found in the Midlands. The succession of the Lower Carboniferous rocks of North Wales evidently furnishes a very simple solution of the problem, and that the whole of the Carboniferous Limestone Series of the Pennine area and Scotland belong to the *Dibunophyllum* and *Seminula* zones, with the possible exception of the Basement beds below the Ash Fell Series of Westmoreland. Hence the contention of Dr. W. Hind that the limestones of the Pennine area are characterised by *Productus giganteus* and its varietal forms is practically correct (Geol. Mag., Dec. IV, Vol. V, p. 69).

In the Bristol area Dr. Vaughan estimates the *Dibunophyllum* zone to be 400 feet thick. It is probably about 500 feet thick in North Wales, but in the Midlands may be from 1,500 to 2,000 feet thick.

The *Dibunophyllum* zone of North Wales can be everywhere divided into an upper and a lower sub-zone as at Bristol, but certain local differences are present.

In the Bristol area *Productus giganteus* with its varietal forms has its maximum towards the base of the Lower *Dibunophyllum* sub-zone, whereas in North Wales this group of shells is not at all common at this horizon, but occurs in the greatest profusion at the top of the Upper *Dibunophyllum* sub-zone. At the quarry at Waenbrodlas, immediately below the *Cyathaxonia* beds, this species occurs in millions, and curiously enough the named varietal forms of this shell occur with it in the same beds. It is apparent, therefore, that the evolution of varietal forms of this species does not afford any help for the purposes of zoning.

The typical transverse forms of *P. giganteus*, as figured by Martin, with long ear-like processes and fine ribs, are accompanied by the broad flat-ribbed form named *P. Edelburgensis* by Phillips, and others less transverse like the specimens figured by Davidson (Brit. Foss. Brachiopoda, pt. v, pl. xxxvii, figs. 1–3).

The Lower *Dibunophyllum* zone is marked by the presence of *Cyathophyllum Murchisoni* in abundance. *Lithostrotion Martini* and its mutations are also fairly abundant. *Dibunophyllum* θ and *D.* φ are also present.

Productus hemisphericus and *P. Cora* are also frequent.

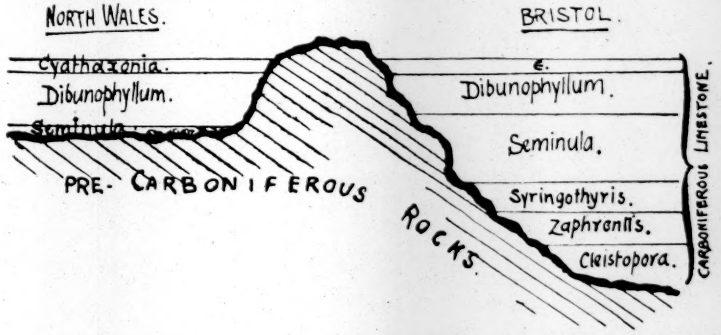


FIG. 4.—Diagrammatic correlation of the Carboniferous succession in the Bristol district and in North Wales.

The Upper *Dibunophyllum* sub-zone is characterised by all the typical fossils of the Bristol equivalent: *Lonsdaleia floriformis*, *L. rugosa*, *Cyathophyllum* cf. *regium*, *C. Murchisoni*, *Lithostrotion Martini*, *L. irregulare*, *L. junceum*, *L. Portlocki*, *L. ensifer*, *Alveolites septosa*, *Dibunophyllum turbinatum*, and *Phillipsastræa radiata*. The fauna is, however, much richer in genera, species, and individuals than that which is present in the Upper *Dibunophyllum* zone of the Bristol area. *Spirifer* and its allies are abundant: *S. trigonalis*, *S. bisulcatus*, *S. planicostata*, *S. striata*, *Reticularia lineata*, *Martinia glabra*, *Athyris planosulcata*, *A. expansa*, *Seminula ambigua*, *Dielasma hastata*, and various forms of *Pugnax* and *Camarotœchia*.

Schizophora resupinata is very abundant and of large size, but *Syringothyris cuspidata* is decidedly rare.

It is in this sub-zone that the well-known rich Carboniferous

fauna of Derbyshire, North Staffordshire, and Yorkshire occurs, and it is an important question as to what conditions determined the paucity of species and genera at the same horizon in the Bristol area.

The presence of *Lonsdaleia*, *Cyathophyllum*, and the smaller species of *Lithostrotion* indicate the line which separates the Upper and Lower *Dibunophyllum* sub-zones in North Wales.

The upper part of the latter zone is characterised by important corals which mark off a definite sub-zone, the importance of which is great because these corals occur at the same horizon in other areas in the Midlands.

These corals are *Cyathaxonia* and a new form which Dr. Vaughan has described as *Amplexi-zaphrentis* (Quart. Journ. Geol. Soc., vol. lxii, p. 215). The history of the latter is of interest, as it was on his determination of these specimens, which I knew came from beds at the very top of the Carboniferous Limestone, to be *Zaphrentis Phillipsi* that we doubted the value of the latter as a zone fossil.

Externally this coral cannot be distinguished from a small *Zaphrentis*, but sections demonstrate structural differences, the septa in full-grown forms not reaching the centre and being attached to the wall by broad bases. They possess tabulæ with a fossula-like depression. Dr. A. Vaughan has published figures of these corals, op. supra cit.

Both *Cyathaxonia* and *Amplexi-zaphrentis* are abundant in the upper beds of the Carboniferous Limestone and in the calcareous shales at the base of the Pendleside Series with *Prolecanites compressus*, at Bradbourne, Derbyshire, near Warslow and Wetton, Staffordshire, in the banks of the Hodder near Stonyhurst, and also at Whitewell, and immediately below the *Posidonomya Becheri* beds in a little stream south-east of Hill Skelterton, near Cracoe. I have also found them at the same horizon at Rainhall Quarry, Barnoldswick, and at the quarry half a mile south of Switchers and one and a half miles W.S.W. of Hellifield.

The range of *Cyathaxonia* and *Amplexi-zaphrentis* denotes the passage beds between the Carboniferous Limestone Series and the Pendleside Series. At Lady McLaren's Quarry, Prestatyn, they lived on until *Pterinopecten papyraceus* appeared.

In North Wales this passage series is complicated by the local presence of the chert beds. The chert beds themselves contain but few recognisable fossils beyond abundance of sponge spicules (*vide ante*, p. 393), and they are immediately succeeded by the black shale and limestones which represent the Pendleside Series in North Wales. We should expect a careful examination of these cherts to yield Radiolarians similar to those which occur in the Culm Series of North Devon, which are probably of the same age.

Just as the oncoming of the deposit of the thick mass of Carboniferous Limestone was gradual and gave rise to local differences in the deposit, so the commencement of the deposition of the thick shale series, the substitution of a detrital for a purely organic deposit, produced divergences which have made correlation somewhat obscure. One fact, however, seems to become more and more

firmly established, that is to say, the cherty deposits of North Yorkshire at the top of the Yoredale Series, the cherts of the Sykes in the Trough of Bolland, North Staffordshire, Derbyshire, the rotten-stones of Glamorgan, and the cherts of Codden Hill, Devonshire, appear from palæontological evidence to be homotaxial and contemporaneous. These cherts succeed beds with a Viséan, or, to be more precise, an Upper *Dibunophyllum* fauna, and in every case except that of North Yorkshire (near Leyburn) are succeeded by the *Posidonomya Becheri* beds of the Pendleside Series. In North Yorkshire it is known that *P. Becheri* beds are absent, this deposit never having been found hitherto in such high latitudes. We do not propose to discuss here the origin of the North Wales cherts. It is sufficient for our purpose to say that the cherts themselves are finely and regularly stratified, that the quantity of chert varies from a high percentage to a small one, that the limestones below the chert are largely impregnated with this mineral, and probably the chert is a replacement mineral.

At the inlier of Carboniferous Limestone at the Sykes in the Trough of Bolland massive cherts, most closely resembling those of North Wales, lie on the top of the upper beds of the Carboniferous Limestone, and are succeeded by black shales of the Pendleside Series. We are not aware that a cherty deposit occurs to that extent anywhere else in that district, but chert is present on the top of the inlier at Withgill. At Pendle Hill the Pendleside Limestone contains numerous strings and nodules of chert. These are of course higher up in the series. At the Sykes the beds are remarkably unfossiliferous, but we obtained sufficient evidence to demonstrate that the limestones belong to the Upper *Dibunophyllum* zones.

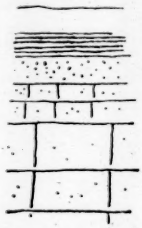
In North Derbyshire remains of a large deposit of chert are to be seen near Pindale, east of Castleton, but on the western flank of the Staffordshire–Derbyshire inlier chert is very irregular in its occurrence. It is, however, present at Mixon below beds with *Posidonomya Becheri*, and in beds, as strings and nodules, containing *Cyathaxonia* and *Amplexi-zaphrentis* at Warslow, and as a cherty limestone on the eastern flank of Thorpe Cloud. On the eastern flank of the Pennines massive chert occurs at Bakewell at the top of the Carboniferous Limestone and above the *Cyathaxonia* beds, in which the black marble of Ashford occurs, this Black Limestone probably being on the same horizon as the 'Aberdo' Black Limestone of North Wales.

In South Wales the Black Limestones of Oystermouth Castle contain *Amplexi-zaphrentis*, and are the representatives of the *Cyathaxonia* zone in South Wales. These beds are in turn succeeded by the rotten-stone beds of Bishopton, evidently decomposed cherts, the equivalents of the Flintshire cherts.

At Bishopton the rotten-stones are succeeded by a black shale series which has a limited but definite Pendleside fauna, *Posidoniella lævis* and *Glyphioceras bilingue*.

[It is necessary to inquire as to what beds, if any, are the representatives of the cherts in those parts of North Wales where they do not occur. The question is one that can only be solved by

palæontology. Wherever the cherts are present in North Wales in sequence we find that they rest on limestones with the *Cyathaxonia* fauna, that is, the uppermost part of the *Dibunophyllum* zone. There are three sections in North Wales which show this sequence; the most easterly is in the road from Brynford to Holywell, where cherts are seen to rest on whitish limestones of the *Cyathaxonia* beds, to be succeeded by black shales and limestones of the Pendleside Series with a typical fauna. Here the cherts are probably not more than 30 to 40 feet thick. Further west, about one mile north-west of Holywell, is the section at the Grange Quarry, Holloway. Here there is the following succession (*vide ante*, pp. 394–395) :—



Cherts with a band of (?) crushed chert.
Shales with *Posidonomya membranacea*.
Cherts, 25 feet; *Acrolepis Hopkinsi*.
Aberdo Limestones (*Cyathaxonia* beds).
Upper *Dibunophyllum* beds.

Fig. 5.—Grange Quarry, Holloway. See also Fig. 1 (xvii).

That is to say, shales with a Pendleside fauna appear between two chert series.

The quarry at Trelogan, four miles further north-west, shows the same sequence. At Pentre, near Gronant, and Talacre the chert beds are very thick, much more evenly bedded than the beds further south-east, and it is not apparent on what beds they rest, but we collected in the cherts *Productus longispinus*, *P. punctatus*, and a spinose form. At these places the cherts are succeeded by black calcareous shales with a Pendleside fauna. At Waenbrodlas the cherts succeed the *Cyathaxonia* beds, and there is no black shale series intercalated in them. In the upper decomposed cherts we collected the fauna, p. 396 (xix), which has a distinctly Upper Carboniferous Limestone character, rather than a Pendleside facies. The fish are certainly Lower Carboniferous forms. South of Waenbrodlas, about ten miles, is a chert quarry at Pant-y-Terwyn, resting on the calcareous pebbly grit of Graianryd, which we think represents the *Cyathaxonia* beds.

So far, then, whenever the chert beds occur they rest on the *Cyathaxonia* beds of the limestone, and the fauna, sparse though it be, has a Carboniferous Limestone facies; but when we examine the sequence in the neighbourhood of Prestatyn, Gwaenysgor, and Teilia we find that its lithological character is completely changed.

Resting apparently conformably on the *Cyathaxonia* beds are some 70 feet of dark limestones of peculiar character, different in numerous details (*vide ante*, p. 451) from the dark limestones of Aberdo character, which it must be remembered also contain a *Cyathaxonia* fauna. The limestones are seen at Teilia, Gwaenysgor, and the hill above Prestatyn. The fauna and flora of these limestones at once fixes their horizon to be the base of the Pendleside Series, and we find the limestones occupying the same relation to

the *Cyathaxonia* beds that we do in various localities in North Staffordshire, Derbyshire, and Yorkshire, i.e. limestones and shales with *Posidonomya Becheri* and *Pterinopecten papyraceus* succeed beds with *Cyathaxonia* fauna. Here, then, the cherts do not succeed the *Cyathaxonia* limestones. Apparently there is no unconformity. The sections at Teilia, the hill above Prestatyn, and Lady McLaren's Quarry opposite Nant Hall seem to point to the sequence being perfectly normal. It must be admitted that the *Posidonomya Becheri* limestones near Prestatyn are far less carbonaceous than beds with a similar fauna which succeed the cherts further east, and that *P. Becheri* itself is much rarer near Holywell than it is at Prestatyn.

Three solutions, neither of which are absolutely satisfactory, offer themselves to this question. One that the cherts near Holywell are the homotaxial equivalents of the *P. Becheri* limestones. Another, that the cherts have been cut out by an unconformity or some result of earth movements.

In favour of the first view: The cherts and *P. Becheri* beds rest everywhere, apparently conformably, on the *Cyathaxonia* beds of the Upper *Dibunophyllum* zone. Where cherts are present the Pendleside Series is characterised by black shaly limestones, which always succeed them. That the limestones and chert beds are both thin-bedded and the beds very finely stratified. That plant-remains have been obtained from the base of the cherts.

On the other hand, the typical Pendleside fauna has not been obtained from the cherts, but the fauna they do contain indicates a somewhat lower horizon.

If the north flank of the hill be followed from Prestatyn eastwards to Lady McLaren's Quarry the section given on p. 451 is seen. These beds rest on *Cyathaxonia* limestones, which are exposed a few yards further west. Continuing eastward along the hill, the outcrop of the *Posidonomya Becheri* limestones is seen as far as Top Nant Farm. East of this farm is a shallow pit, from which similar limestones were obtained. Some 200 yards south of this pit is another shallow excavation which shows chert débris, and in such condition and quantity as to indicate the broken up bed of chert. No junction is seen, but it would seem that a bed of chert may here overlie *P. Becheri* limestones. The general dip of the beds is north-east, and this outcrop of chert is about 470 feet above O.D. The next most easterly exposure of chert is a quarter of a mile away in a dingle west of the road over the hill to Teilia and Gwaenysgor. This is in the 200 feet contour, and the beds are dipping very highly and evidently near a fault.

For the present, then, the precise reason for the absence of the cherts immediately in succession of the *Cyathaxonia* beds is not apparent, and it is possible that they are the homotaxial equivalents of the *Posidonomya Becheri* limestones.

The difficulty of correlation has been enhanced by the unfortunate assumption that Black Limestones were all on the same horizon. There are no less than three series of Black Limestones each with a definite fauna: the Black Limestones of the Holywell shales and

Teilia Beds with *P. Becheri*, the Black Limestones (Aberdo) of Holloway and Trelogan with *Cyathaxonia*, and the Black Limestones of Prestatyn with *Zaphrentis* aff. *Enniskilleni*. Probably the latter two are nearly on the same horizon, and both must be included in the Upper *Dibunophyllum* zone. This Zaphrentoid coral has occurred in the same zone at Bradbourne, Derbyshire, and Rush, co. Dublin. There is no doubt that the cherts overlie the lower set of Black Limestones, but it is their relation to the *Posidonomya Becheri* limestones which has been questioned. The idea that the cherts are the homotaxial equivalents of the Millstone Grit is obviously untenable on palæontological grounds, the more so if *P. Becheri* beds occur above them.

The third solution of the question is that the chert beds occur at different horizons in the series at different localities, that they are higher at Pentre and near Gronant than they are near Holywell, Trelogan, and Waenbrodlas. We know that cherts occur at many horizons in the Upper *Dibunophyllum* beds of Derbyshire, both in and below the *Cyathaxonia* zone. It is of the utmost importance that the junction of the *Cyathaxonia* beds and the *Posidonomya* beds should be recognised and mapped, because the junction is the division between the Upper and Lower Carboniferous Series in the Midlands. At this point the great faunal change takes place, at this point the new fauna comes in, and moreover the faunal change corresponds with well-marked change in lithological characters, provided that the mere colour (black) is not allowed to cause confusion of limestones on two distinct horizons.]

6. The Pendleside Series.

In the neighbourhood of Prestatyn and Holywell the Pendleside Series is well represented, typical fossils, flora and fauna, being common. Immediately above the cherts are peculiar black limestones of definite character (*vide ante*, pp. 450, 454), which are exactly similar to those found in the lower part of the Pendleside Series anywhere in the Pennine area.

We have not yet found the lowest zonal fossil of this series, *Prolecanites compressus*, in North Wales, except possibly at Teilia. *Posidonomya membranacea*, *P. Becheri*, and *Pterinopecten papyraceus* are abundant in many localities. The first two species may be considered as absolutely characteristic of this horizon, having never yet been found in higher beds.

At Teilia Quarry the following plants have been obtained, and Mr. Kidston gives the following list, op. supra cit. A fine collection is in the Grosvenor Museum, Chester, and we owe our thanks to Mr. A. Newstead, the Curator, for an examination of the specimens.

**Adiantites antiquus.*
Sphenopteris Teiliana.
**S. subgeniculata.*
S. striata.
**S. pachyrachis.*
* ,, var. *stenophylla.*
? *S. Schlebani.*
S. affinis.
Rhacopteris glabellata.
R. inequilatera.
? *Archeopteris* sp.
**Asterocalamites scrobiculatus.*
Lepidophloios sp.

Those species marked by an * have been obtained from beds containing the same fauna at Poolvash, Isle of Man, Pendle Hill, and North Staffordshire.

The number of specimens found in various localities is remarkable when the marine character of the deposit is considered. The presence of drifted plants at any place must be purely due to currents and the proximity of land.

There can be no doubt, then, that the palæontological evidence definitely correlates the Teilia Beds with the lower part of the Pendleside Series of the Midlands and the *Posidonomya Becheri* beds of the Culm. Between Holywell and Bagillt the shaley division of the series is well developed and reaches a normal thickness. The beds are difficult to examine in detail, but we know that the peculiar mutation of *Productus Cora* which characterises beds of this horizon elsewhere is present in abundance (*vide ante*, p. 454).

From Holywell south the black shale series are only occasionally exposed, as they occupy the flat country east of the limestone escarpment.

In the ravine of Nant Figillt Wood, shales with *Lingula* and obscure fish-remains appear to succeed limestones containing *Amplexi-zaphrentis* and *Cyathaxonia*, and the brick-pits near Hendre gave a dark earthy limestone crowded with *Posidoniella lævis*, *Glyphioceras reticulatum*, and *Dimorphoceras Gilbertsoni*, so that here we get evidence of a zone of the Pendleside Series much higher in the succession than the *Posidonomya Becheri* beds, which corresponds to the black fossiliferous limestones of Horsebridge Clough, High Green Wood, near Hebden Bridge. South of Hendre exposures of the shale series are very few. The Survey mentions the occurrence of *Posidonomya* and *Goniatites* in shale with cement stones in the River Terrig, some miles further south. It is to be regretted that the species were not determined.

All through the Midlands and North Wales the southern limit of the Pendleside Series is marked by a very rapid thinning-out, and it is rather singular that this practically coincides with a latitude of 53° N. The following table illustrates the remarkable variation of thickness in these beds that takes place within about ten minutes of latitude :—

Locality.	Latitude N.	Thickness, feet.
Holywell, Co. Flint	53° 16′ 20″	1000
Near Buxton, Co. Derby	53° 16′ 0″	(about) 1000
Morridge, Co. Stafford	53° 7′ 0″	1000
Llangollen, Co. Denbigh	52° 58′ 0″	18–50
Lilleshall, Co. Salop	52° 44′ 40″	absent
Ticknall and Grace Dieu, Co. Leicester ...	52° 48′ 0″	30 to 40

It is interesting, therefore, to note in this particular also the intimate relation of the North Wales development of the Pendleside Series with the larger Pennine area.

7. Notes on the Palæontology.

Daviesiella (*Productus*) *Llangollensis*, Davidson, sp. Waagen (Mem. Geol. Surv. India: Palæontologica Indica, ser. xiii, vol. i, No. iv, p. 613) says: "I create this genus for the reception of such forms as *Productus Llangollensis* and *Chonetes comoides*, Sow., which

are characterised by cardinal teeth and a second pair of adductor impressions in the ventral valve. The other characters are like those of *Productus*."

He has omitted two very important characters which are present in the former species. These are a well-marked area and a hollow beneath the beak of the brachial valve, two characters which in addition separate the species from *Productus*. The extraordinary thickness of the brachial valve of this species is very remarkable, reaching in some cases to one inch.

Productus giganteus. A good deal of detailed work requires to be done on the shells which come under this group name. It is questionable whether all really, *sensu stricto*, can come into the genus *Productus*. In some specimens there is a distinct area and other characters which point rather to an affinity with *Chonetes*. We have mentioned in the text that the group which we temporarily allude to as *P. giganteus* lived together, and that the variant forms or mutations have no value as an index of time.

Productus antiquatus. A very elegant reticulate form belonging to this genus is not uncommon throughout the *Dibunophyllum* zone of North Wales. We know it from the Midlands at the same horizon. It is distinct enough to deserve a specific name, which will doubtless be given to it when the genus is revised.

Productus Cora. We have retained this name for the present, on the statement of de Koninck that D'Orbigny's type from Bolivia was identical with the Belgian species, although neither the original description nor figure is good.

The careful search for fossils in the North Welsh Carboniferous rocks has yielded no new forms, but certain details of the fauna are worth recording.

In the limestone the number of species of each group of organisms, except the corals, is much less than are present at the same horizons in the Derbyshire and Staffordshire inlier of Carboniferous Limestone. Of the Mollusca the Cephalopoda are only represented by about half a dozen species, and individuals are extremely rare. Both Gasteropods and Lamellibranchs are comparatively as rare as the Cephalopods. Morton quotes about 30 of each family. The Brachiopoda, as might be expected, are more common, and are represented by about 50 species. In this group individuals are frequent, but not so common as in the Midlands.

The only species which occurs in North Wales and has not yet been found in North Staffordshire or Derbyshire is *Allorisma maxima*, Portl., sp., the *Sanguinolites clava* of Morton's list. In the paucity of species and individuals North Wales agrees with the Bristol–Mendip area. Conditions, therefore, must have been very similar.

P. membranacea has a very limited vertical, but a wide horizontal, range. It is always found in black shale or dark limestone immediately succeeding beds with a Visćan fauna. It has been found in this position from the west coast of County Clare to Clavier in Belgium, and it must therefore be regarded as a definite zonal index of the lower part of the Pendleside Series.

8. Summary.

In conclusion, the main results of our researches in the Lower Carboniferous rocks of North Wales may be epitomised as follows:—

1. The classification of these rocks here given is absolutely based on palæontological data: it has been shown that all the errors in previous work can be traced to the subordination of palæontology to the lithological features of the strata.

2. The sequence exhibited in the area under examination is perfectly normal to that obtaining in other areas of the North Midlands, which afforded the key to the simple explanation of the succession in this district. For the purposes of correlation the perfection of the geological record has exceeded our most sanguine expectations.

3. The Holywell shales have been proved to be the equivalents, lithologically and palæontologically, of the Pendleside Series.

4. The lower series of the Carboniferous Limestone as developed in the Bristol area was never deposited in these parts, whose lowest beds are characteristic of a comparatively late phase of the Carboniferous Limestone period. Whether this was altogether due to irregular configuration of the ocean floor of that age, or to contemporaneous earth-movement of a specially regional character, it is much too soon as yet to argue with assurance.

Our thanks are largely due to Dr. A. Vaughan, who has kindly looked over a large number of Corals and Brachiopods and compared them with the forms occurring in the upper portion of the Bristol Carboniferous area. We also have to thank Dr. A. Smith Woodward and Mr. R. Kidston for the determination of some fossil fish- and plant-remains.

IV.—The Zones of the Lower Chalk.

By A. J. Jukes-Browne, B.A., F.G.S.

In the September number of this Magazine Mr. T. O. Bosworth raises some questions with regard to the zoning of the Lower Chalk in general, and of Cambridgeshire in particular. As I am responsible for the subdivision of the Lower Chalk of this country into zones I suppose the matter concerns me more than anyone else.

The two main questions raised by Mr. Bosworth are (1) the zonal position of the Totternhoe Stone, (2) the propriety of using *Holaster subglobosus* as an index for the higher zone. He may be sure that both these points were fully considered by me when compiling the account of the Lower Chalk for the Geological Survey Memoir on Cretaceous Rocks, and he is probably aware that the second point was discussed in the second volume of that Memoir (chapter ii, p. 17).

With respect to the Totternhoe Stone, Mr. Bosworth should explain why he uses the term "Burwell Rock"; this name may be current at Cambridge, but it cannot supplant the older name of Totternhoe Stone, and his own diagrams show that he accepts the identity of the stone beds at Totternhoe and Burwell.

Next as regards the zonal position of the Totternhoe Stone. The reasons for placing it in the higher rather than in the lower zone were stronger than he imagines them to have been. If he had referred to my first paper on "The Subdivisions of the Chalk"[1] he would have found that under the head of Totternhoe Stone a special point was made of the occurrence of a nodule bed at its base, and attention was drawn to certain fossils as characteristic of the stone. The reasons which weighed with me when compiling the General Memoir were the following:—

1. The frequent signs of current erosion at or near its base, and the change of physical conditions thus indicated.

2. The presence of certain fossils which are generally characteristic of higher beds and are rarely or never present in the Chalk Marl of those counties in which the Totternhoe Stone is typically developed. The chief of these are *Acanthoceras rotomagensis*, *A. cenomanensis*, *Haploceras Austeni*, *Actinocamax lanceolatus*, *Pecten Beaveri*, *P. elongatus*, *P. fissicosta*, *Lima echinata*, *Enoploclytia Imagei*, and more rarely *Holaster subglobosus*.

3. The fact that the stone passes upward into the overlying chalk without any sign of physical change.

Mr Bosworth has a curious method of estimating the affinities of a fauna, for he does not deal with the actual fauna of the Totternhoe Stone, but takes the fossil assemblages in the beds below and above it, and calculates how many species of each occur also in the intermediate band. This is certainly not the usual way, and can only be interesting as throwing a kind of sidelight on the subject, and this only when the comparison is fairly made. With this object Reptilia should be excluded, seeing that none occur either in the Chalk Marl or in the Totternhoe Stone of Cambridgeshire.

When only the same classes of animals are allowed to enter into the comparison the results are different from those given by Mr. Bosworth. The proportion of Chalk Marl species which range up is the same, namely 92 per cent., but the proportion of the species ranging down from the higher beds into the Totternhoe Stone is 33 out of 42, i.e., 78 per cent. instead of only 67.

If, however, the usual and more rational method is employed, and a larger area is included by taking in the lists from the counties of Bedford and Hertford, where the Totternhoe Stone is typically developed, we shall certainly get a more reliable estimate of the relations of the fauna of that stone to those of the beds above and below. Excluding reptiles but including fish the fauna of the Totternhoe Stone (as recorded in the General Memoir) comprises 96 species; of these only 23 range downward into the Chalk Marl of the counties mentioned, while no fewer than 45 range up into the overlying beds[2]; in other words, twice as many range upward as downward, and the natural conclusion is that the fauna of the

[1] Geol. Mag., Dec. II, Vol. VII (1880), p. 251.

[2] This number includes those recorded by Mr. Bosworth, but omits three Cephalopoda which have only been found at Orwell in a quarry which may or may not be above the Totternhoe Stone.

Totternhoe Stone has much more affinity with the beds above than with the beds below.

I record this result as an answer to Mr. Bosworth's peculiar mode of dealing with the matter, but I do not wish to lay much stress on the argument, for I regard mere percentages as deceptive and unsatisfactory tests, unless the abundance of characteristic species is taken into account. I am quite disposed to give due weight to the fact that *Schlœnbachia varians*, *Scaphites æqualis*, and several species of *Turrilites*, which are important members of the southern Chalk Marl fauna, occur also in the Totternhoe Stone. Indeed, I regard this stone as a band of rock developed at the junction of the two zones at a time when some species were dying out and when others were coming in, so that it might with equally good reason be placed in either zone.

I have stated the reasons which originally induced me to regard it as the base of the higher zone, and I do not see that any clearer idea of its real position as a passage bed would be gained by transferring it to the zone of *Ammonites varians*. My own feeling is that the matter had best be left where it stands until a larger body of evidence has been obtained.

I have next to deal with Mr. Bosworth's statements regarding the recorded occurrences of *Holaster subglobosus* and *H. trecensis*, some of which are certainly incorrect, while others require confirmation.

He states that *H. subglobosus* is nearly as common in the zone of *A. varians* as in the beds above throughout Hampshire, Wiltshire, Isle of Wight, Sussex, and Kent! So far as I know this is only true of the Isle of Wight, and the rest of the statement absolutely contradicts that made by me in the General Memoir above mentioned (vol. ii, p. 17). It is true that Mantell recorded *H. subglobosus* from Middleham, Mad'cock found it in the Chalk Marl of Eastbourne, and Etheridge in that of Folkestone, but so far as I know these records have not been confirmed by later collectors. On the other hand, this urchin is a common fossil in the central part of the Lower Chalk throughout Kent and Surrey, as well as at Lewes and Eastbourne in Sussex. If Mr. Bosworth has any special information about the distribution of this fossil in the counties mentioned he should publish it.

Again, I am obliged to contradict his statement that *H. subglobosus* is a rare fossil above the Totternhoe Stone in Lincolnshire and Yorkshire. Such an idea can only be due to careless reading of the records and descriptions given by Mr. W. Hill and myself. In the General Memoir (vol. ii, p. 20) I wrote: "*Holaster subglobosus* is not uncommon in these beds both in Yorkshire and Lincolnshire, but it is equally common in the zone of *Am. varians*, so that it will be more convenient to take *Offaster sphæricus* as the index of the zone in these counties."

With respect to *H. trecensis* I shall be glad to know on what authority Mr. Bosworth asserts that in Dorset and Devon this species "is plentiful in the beds above the *A. varians* zone, . . . is almost confined to the zone and could well be used as the zone

fossil." So far as my experience goes it is not plentiful in either zone, but is occasionally to be found in Dorset near the base of the *A. varians* zone and near the top of the *H. subglobosus* zone. As regards Devon I am at a loss to know what he means!

Mr. Bosworth also states that *H. trecensis* "is common throughout the [upper] zone in Hants, Sussex, Kent, and the Isle of Wight." He writes as if this was a well-known fact or could easily be gathered from a perusal of the Survey Memoirs, whereas I do not think that any such statement has been made either in these memoirs or in any other publication, except with regard to the Isle of Wight. In Sussex it would seem to be a scarce fossil, for I was not able to record the occurrence of a single specimen from the zone of *H. subglobosus*.

The only satisfactory and useful part of Mr. Bosworth's article is the record of his own observations near Cambridge. I have no reason to doubt the accuracy of these, and am quite ready to accept his statement that *H. trecensis* is more abundant than would appear from the lists in the Memoirs of the Geological Survey, and also that it occurs chiefly in the upper half of the zone, while *H. subglobosus* occurs more abundantly (if not exclusively) in the lower half.

I believe that the same distribution of these two species prevails in Hertfordshire, Bedfordshire, and Buckinghamshire, as well as in Hampshire, Surrey, and Kent. This is a point which is well worth further investigation, and if their relative abundance proved to be the same as in Cambridgeshire, it might lead to the establishment of the two subzones which are suggested by Mr. Bosworth.

I do not think, however, that his proposal to substitute the term "Lower Holaster zone" for the zone of *H. subglobosus* will meet with acceptance. There are several obvious objections to it which it is hardly necessary to specify, and, in fact, he does not seem satisfied with it himself, for in the table with which his article concludes it is replaced by the designation of "Two Holasters zone." He might at least have made up his mind to use one or the other and not both.

I am quite prepared to admit that *H. subglobosus* is not a satisfactory index to the zone, but the real question is, can a more satisfactory one be found?

This question was briefly discussed in the introductory chapter to the second volume of the Memoir on Cretaceous Rocks, and I wrote that "so far as we know at present there is no species which is restricted to the upper part of the Lower Chalk, and is at the same time common enough in every district to be a useful index." When preparing that memoir I hoped that *Haploceras Austeni* would prove to be such a fossil, for though it is not very common it would have served well enough if its range had been limited to the zone. Unfortunately, however, near Lewes, in Sussex, it occurs in the zone of *A. varians* and has not so far been recorded from the higher zone in that county.

Sharpe, in describing his *Ammonites Austeni*, states that it is common in the Guildford district of Surrey, but no one has yet ascertained in which zone it there occurs. It is fairly common in

the zone of *H. subglobosus* of Wiltshire and Berkshire, but has not yet been reported from Hampshire, Kent, Isle of Wight, Dorset, Oxfordshire, Buckinghamshire, or Hertfordshire.

With regard to *Acanthoceras rotomagensis* it cannot be regarded as a better guide than *H. subglobosus*, for in many of the southern counties it is fairly common in the zone of *A. varians*. North of the Thames, however, it seems to be restricted to the higher zone until we reach Norfolk, where it again occurs in the zone of *A. varians*, as it does also in Yorkshire.

There remains only the larger form of *Discoidea cylindrica*, a species which is generally much more common in the upper part of the Lower Chalk than in the lower part. In the south of England it has only been recorded from the zone of *A. varians* in Dorset and Somerset, and by Mantell from Hamsey in Sussex (not since confirmed). It is indeed a common fossil of the lower zone in Yorkshire, Lincolnshire, and Norfolk, but the form there found is the depressed variety, and if any constant structural differences can be found to distinguish this variety from that which prevails in the higher zone the latter might perhaps be utilised as an index for that zone.

To sum up, therefore, it would seem that our knowledge of the distribution of the fossils of the Lower Chalk is not yet sufficiently complete to enable us to decide on any substitute for *H. subglobosus* as an index. It may be that *Haploceras Austeni* would be a better one in spite of its occasional occurrence lower down, or it may be that the taller hemispheric variety of *Discoidea cylindrica* will be preferable. More information is required about both, and meantime I am sure that it would be undesirable to make any alteration in the current nomenclature, and I do not think that the terminology proposed by Mr. Bosworth would at any time be an improvement.

V.—The Source of the Waters of Geysers.

By J. Malcolm Maclaren, B.Sc., F.G.S.,
Geological Survey of India, Calcutta.

PROFESSOR SUESS has somewhat recently stated his belief that the waters of all geysers and boiling 'pulsating' springs and of some mineral springs are of 'hypogene' or direct magmatic origin (Abstract Geog. Journ., vol. xx, p. 518). I am unfortunately unable in this backwater of science to verify the abstract by reference to the original (Gesell. Deutsch. Naturforscher und Aertze, 1902). With his belief, however, several prominent Continental and American geologists have expressed their concurrence, and some have indeed amplified the hypothesis to cover the origin of metalliferous deposits near igneous contacts. For example, W. H. Weed (Trans. Amer. Inst. M.E., vol. xxxiii, p. 746) says:—

"I hold that the metallic contents of such veins are not gathered by ordinary meteoric water, as maintained by Van Hise. The water content of the sedimentary rocks (ground-water) present at the time of eruption was expelled by contact-metamorphism. The ore-forming solutions were in part of direct igneous origin (i.e. primitive

or igneogenous; the geyser waters of Iceland, New Zealand, and the Yellowstone regions are probably mainly of this character, as maintained by Suess); these primitive hot vapors and waters rise and penetrate the zone of circulating meteoric waters, heating the latter and charging them with both metallic salts and with fluorine, chlorine, bromine, and other mineralizing agents."

Recent geyser phenomena in New Zealand have led me to doubt more than ever the validity of this inference of Suess. New Zealand contains one of the most active of fumarolic areas, and, curiously enough, the life-history of its greatest geyser—the greatest also that the world has yet known—is strikingly illuminative of the subject under discussion. For confirmatory details of the history of this geyser I am indebted to the courtesy of Mr. Colin Fraser, of the New Zealand Geological Survey. Waimangu Geyser was discovered in January, 1900, but it had doubtless been in existence for a short time prior to that date. Its basin was then some 130 feet long and 80 feet wide, at ordinary times full of black muddy water. Although it played almost daily, its eruptions were most irregular in character, sometimes expending their energy in a single outburst, hurling a mass of water estimated at 800 tons to a maximum height of 1,500 feet, at other times playing lightly and intermittently for five to six hours. The intervals between eruptions were rarely more than 30 hours. For more than four years after its discovery Waimangu was in active eruption, but during July and August, 1904, it remained quiescent for nearly two months. After this period of inactivity it recommenced its eruptions with unabated and indeed often increased energy, and so continued until 31st October, 1904, when, with the exception of a feeble eruption on the following day, it ceased spouting, and now remains dormant or is extinct—a flowing pool with a temperature of 130° F.

The modern history of Tarawera Lake, four miles to the north-east of Waimangu, is important in this connection. The explosive eruption of Tarawera Mountain in June, 1886, threw a great ash barrier across the valley which formed the natural outlet for the waters of Lake Tarawera. (For a graphic description of this Tarawera rift area, *vide* Geog. Journ., April, 1906.) The level of the lake at once rose some 28 feet, and after some time, as the outlets through the ash barrier became choked with débris, continued to rise still further. By the end of October, 1904, the waters had risen another 14 feet. At that height and on the 1st November, *the day on which Waimangu last played*, the waters overtopped the barrier. On the following day the level of the lake had fallen three feet, and on the 3rd November the barrier was carried away. The waters of the lake rushed over the Tetauahape escarpment and escaped by an old channel at the rate of more than a million and a half cubic feet per minute, forming, for the few days they lasted, a stupendous cataract. The level of the lake is now eleven feet below the maximum height of 1904, and its waters now escape by the normal subterranean channels, which from Maori legends are known to have been in existence for centuries.

In Waimangu Geyser itself there has been no recrudescence since the breaking away of Lake Tarawera, and in the immediate vicinity there has been one outburst only. This took place on 21st February, 1906, at Frying Pan Flat, but lasted only a few hours. Frying Pan Flat is, however, an old geyser crater that had been in eruption during the period of Waimangu activity. Thermal relief along the Tarawera rift is now effected by comparatively mild eruptions, the character of which would seem to indicate expulsion from slowly filling subterranean reservoirs.

Other large geysers in the New Zealand area show or have shown a degree of dependence on superficial waters. Dr. Wohlmann, Government Balneologist, instances the case of the Crow's Nest Geyser at Taupo, on the banks of the Waikato River, near its emergence from Lake Taupo. When the Waikato River is in flood the Crow's Nest Geyser plays every 40 minutes. With low waters the interval is increased to two hours. At Orakeikorako, some fifteen miles to the north and also on the banks of the Waikato River, the great geysers last played when the Waikato River was abnormally high. Thermal manifestation at Orakeikorako has since been confined to hot springs.

Every gradation from Waimangu through boiling springs to faintly bubbling warm pools are known in the New Zealand area, and it seems impossible to make any genetic distinction between the most active and the more lethargic members of the series. Yet some of the latter are obviously dependent for their waters on surface supplies. The heat necessary to create the motive force of these geysers lies certainly at no great depth. For many years after the 1886 eruption it was possible to char wood by plunging it into a crevice in the ash beds. While, therefore, the heat supplied to the geysers may certainly be considered magmatic, it is nevertheless directly applied, and is not carried to the geyser tube by magmatic waters and vapours such as have been called into existence in the passage quoted in the first paragraph of this communication.

Nor even in this New Zealand region, the evidence from which points to the meteoric origin of geysers and hot springs, is the evidence of contemporaneous metallic deposition lacking. By the courtesy of the New Zealand Geological Survey I am enabled to publish two interesting analyses, or rather assays, made by the Colonial Analyst, of fumarolic deposits from Whakarewarewa, immediately south of Rotorua. Siliceous sinter taken from the sides of a trough used to conduct hot water from a large pool behind the Geyser Hotel gave —

	dwts.	grs.	
Gold	0	12	per ton.
Silver	15	3	,, ,,

while a sulphurous sinter formed on the edge of the spring showed :—

	ozs.	dwts.	grs.	
Gold	0	1	4	per ton.
Silver	4	0	18	,, ,,

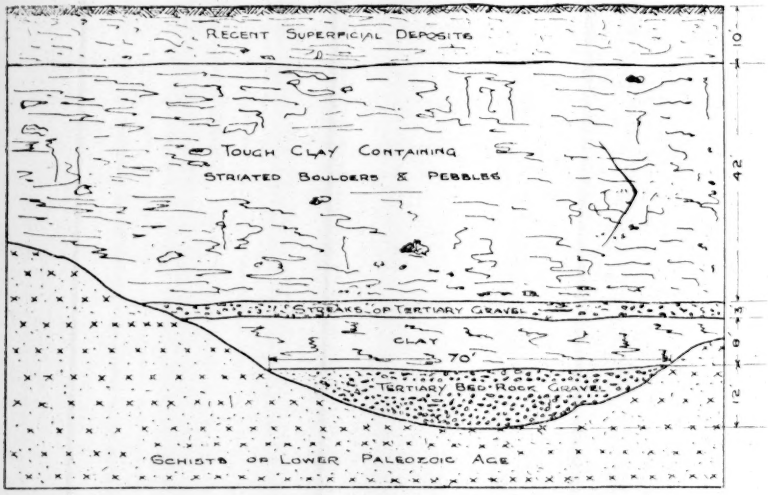
both most suggestive results.

While it is at once admitted that the foregoing facts are not in themselves sufficiently correlated to justify the assumption of a meteoric origin for all geysers and most metalliferous solutions, they may nevertheless be considered sufficiently suggestive to give pause to the most imaginative of magmatic secretionists. In view of the undoubted connection between heated waters and ore deposition, further detailed and scientific study of these fumarolic areas is greatly to be desired.

VI.—Some Further Considerations of the Genesis of the Gold Deposits of Barkerville, B.C., and the Vicinity.

By Austin J. R. Atkin, Esq.

SINCE the publication of my paper "The Genesis of the Gold Deposits of Barkerville,"[1] the frequency with which it has been suggested to me that the gold in the placers spoken of might have been precipitated *in situ* has led me to place before you the reasons for ascribing to it the origin therein stated.



SECTION OF FILLING, ANCIENT CHANNEL, LOWER WILLIAMS CREEK CARIBOO. B. C.

In propounding the theory of precipitation to explain the occurrence of nuggets in the Australian 'leads' Professor Newberry took into account the fact that it was only at considerable distances from the source of the leads that the larger nuggets were found. He also noted that the greatest accretions of gold were where the wood found in these old channels was most abundant; that as a rule the gold contained a nucleus of iron; that it was finer in

[1] Quart. Journ. Geol. Soc., vol. lx (1904), pp. 389–393.

quality than any found in the adjacent reefs. In the deposits the source of which I have tried to indicate, the very reverse of these conditions may be said to exist.

The general characteristics of these old channels, that is the filling of the ancient creek beds, consist of—

1. Pre-Tertiary gravels in the bottom.[1]
2. Tough clay containing striated boulders and pebbles, with streaks of pre-Tertiary gravels washed from upper portions of the creek during recessions of the ice-cap.
3. Recent superficial deposits.
4. No wood has been found in the channels.

The gravels in the creek bottoms are the harder detritus from the hill-sides, the softer having been disintegrated and removed by the heavy rains of later Tertiary times.

The gold occurrence has always been in the type of a deposit sorted in rapidly moving water.

The heavier and rougher pieces at the top become smaller and more water-worn as the creek is followed down from its source, while behind some of the larger boulders a remarkable concentration of gold has taken place.

The fineness of the gold varies in different creeks; and it can always be recognised, even when mixed, as below the junction of two channels.

In some instances different parts of the same creek were distinguished by varying grades of gold, while in one case there was a noticeable increase in returns below a large quartz reef, although this reef itself is now valueless, and the richness varied along the channel. This instance should be given due prominence when considering the possibility of a detrital or accretionary origin for the gold.

All the specimens submitted are from one creek. The larger nuggets, $\frac{A}{1}$, $\frac{A}{2}$, etc., are from the upper portion, those marked *B* are from the middle, while the smaller grains in the vial *C* are from the lowest ground worked.

It will be noticed that the specimens from the head of the creek are large and not much worn, $\frac{A}{1}$ scarcely at all, while $\frac{A}{2}$, $\frac{A}{3}$ are typical specimens of quartz gold such as may be chipped from any rich outcrop at the present time.

Specimen *D* is from a boulder found in Snowshoe Creek. This rock weighed over 250 lbs., and was extraordinarily rich. It shows gold intimately associated with iron pyrites and also in the quartz alone. Had this rock experienced sufficient attrition to set free the gold we would have had nuggets like $\frac{A}{1}$, $\frac{A}{2}$, etc., while the smaller pieces might have travelled further down the creek to become similar to the inbits *B* and *C*.

Specimen *E* contains gold panned by the writer from a quartz outcrop on Lowhee Creek, which would have yielded nuggets similar to those now found in the placers had the outcrop been eroded sufficiently.

[1] See section.

These specimens, which might be largely augmented if required, are sufficient to account for the origin of most of the gold.

The occurrences, graduating from coarse to fine, typical of water-sorted deposits, the variation in the quality of the gold in different parts of the same channel, the assay value varying between about 850 and 910 as it does in the reefs, must, taken together, place the detrital origin of the greater part of the gold beyond dispute.

It may still be suggested that some of the gold is a precipitate in the drifts. Even this seems unlikely in view of the shortness of the creeks and the small size of the nuggets found.

The largest nugget ever discovered in Cariboo County did not exceed 40 ounces in weight, and that was taken from Butcher Bench on Lightning Creek, the remains of a channel in which the water ceased to flow while the creek cut down through ninety feet of rock to the bed of the deepest channel.[1] Were the gold here of accretionary origin, surely the deepest channel would have contained the largest nuggets, instead of smaller pieces so scratched and worn as to distinctly show their origin to be detritus from a higher level, worn and broken up in the bed of a mountain torrent.

If it be argued that the deposits are too recent for any but small accretions to be found, exhibit $\frac{C}{2}$ is an instance of a small particle embedded in quartz which very little attrition might have set free to mislead investigators.

The small piece on the back of *D* would have been another piece whose true origin would with difficulty have been determined. Then, again, I am informed[2] nuggets are found in the clay, though this is not quite certain. These cannot be the result of percolating water, as this clay is very compact and quite impervious to solutions. The specimens shown to me as derived from this source had a large proportion of quartz in them, and are more likely to occur in one of the streaks deposited during recessions of the ice-cap, probably as fragments from such boulders as *D* came from, which it required the violence of the torrential waters from the melting ice-cap to disintegrate to the size of pieces whose gold contents saved them from further fracture, while the same torrents swept the smaller pieces down to the receptacle of the waters of that period, as Dr. Dawson suggests a lake occupying the basin from Soda Creek to the Nacahaco, while its western boundary reached to what is now the Kluskus-Ulgacho[3] watershed.

List of specimens submitted from Barkerville, B.C., and its vicinity.

Various nuggets marked $\frac{A}{1}$ $\frac{A}{2}$ $\frac{A}{3}$ $\frac{A}{4}$ $\frac{A}{5}$ $\frac{A}{6}$ $\frac{A}{7}$ $\frac{C}{2}$.
Piece of quartz showing free gold, marked *D*.
Bottle of quartz gold from Lowhee Creek, marked *E*.
Tube of gold from Middle Williams Creek, marked *B*.
Tube of gold from Lower Williams Creek, marked *C*.

[The above specimens have been received by the Editor GEOL. MAG.]

[1] "Notes on the Gold Occurrences on Lightning Creek": GEOL. MAG., March, 1905.
[2] R. S. Robinson, Resident Engineer, Cariboo Goldfields, Ltd., Alluvial Mining.
[3] Two Indian villages whose positions can easily be seen on maps.

NOTICES OF MEMOIRS.[1]

I.—On Faults as a Predisposing Cause for the Existence of Pot-holes on Ingleborough. By Harold Brodrick.

INGLEBOROUGH Hill consists of a large plateau of Carboniferous Limestone about 500 feet in thickness and capped by a cone of Yoredale rocks with a summit of Millstone Grit. On this plateau there are a large number of pot-holes or vertical shafts in the limestone: there are upwards of thirty of these at present known to exist, and it is probable that there are many more still covered with the deposit of glacial drift. Within the last few years many facts have come to light which prove that many, if not all, of the deeper pot-holes owe their existence to faults. Rift Pot, a pot-hole on the south-east side of the hill, was recently explored and found to extend to a depth of over 300 feet: the first portion consists of a vertical shaft 114 feet deep, the lower portion of which consists of a chamber 130 feet long and 25 feet broad; from the south end of this the pot descends for a distance of about 200 feet with a series of platforms of jambed stones wedged between the walls of a vertical fissure, finally ending in a short passage which at the end is waterlogged. The pot-hole at the surface takes the form of a fissure 60 feet long and from one to seven feet wide. At the northern end of this fissure, within a few feet of the moor level, the east wall is slickensided, and in the main chamber at the foot of the first shaft the east wall is also slickensided, over an area 50 feet in length and at least 20 feet in height. At the surface the slickensides occur along successive master joints, while those in the main chamber occur along another master joint at a horizontal distance of about 15 feet. These slickensides are horizontal, showing that the fault was one of horizontal displacement, and as a careful examination shows that the beds of limestone on either side of the upper part of the pot correspond, it is clear that no vertical movement accompanied the faulting. The slickensides near the surface are coated with clear crystals of calcite, which when removed leave the slickensides very clearly marked.

Only one fault is marked on the maps of the Geological Survey: this is a fault which runs from near Horton to God's Bridge, in Chapel-le-Dale. Along the line of this fault are several pot-holes, all of which have their longer axes in the direction of the fault. Sulber Pot, which is about 59 feet deep, and Nick Pot, which receives an inflowing stream, and has recently been explored to a depth of about 80 feet, exhibit no direct evidences of faulting; but Mere Gill, on the other hand, does. Mere Gill consists of a fissure, about 80 yards long, which is bridged in three places by rock. As a rule this fissure is filled with water to within 30 feet of the surface; in times of normal rainfall the water escapes through a tunnel below the water-level, which leads in a southerly direction (away from the valley); it then makes two vertical descents of 80 feet each and turns northwards to emerge in the valley near God's Bridge in the direct line of the fault. On the limestone, which is usually covered

[1] Abstracts of six papers read before the British Association, Section C (Geology), York, 1906.

by the stream falling into the pot, are crystals of calcite. These are very much water-worn, but clearly indicate the existence of a fault.

Gaping Gill consists of a vertical shaft, 365 feet deep, into which the waters of Fell Beck fall. At a depth of about 190 feet is a ledge some 12 feet wide: at this point a fault is very clearly to be seen; the fault has a downthrow of six feet to the south. The shape of practically all the pot-holes is a further indication that they have been formed as the result of faults: they are all much longer than they are wide, and thin out at each end into a narrow crack. It is also a noticeable fact that they occur in groups and in such positions that it would have been impossible for a stream to form more than one out of several.

II.—Jurassic Plants from the Rocks of East Yorkshire. By A. C. Seward, M.A., F.R.S.

Historical.—The work of Young and Bird, entitled "A Geological Survey of the Yorkshire Coast," was published at Whitby in 1822. William Bean, John Williamson, and William Crawford Williamson rendered excellent service in the early days of the geological exploration of the Yorkshire coast. Several specimens collected by local naturalists were sent to Adolphe Brongniart, and described by him in his "Histoire des Végétaux Fossiles," published in 1828. The publication in 1829 of "Illustrations of the Geology of Yorkshire," by J. Phillips, placed the geology of East Yorkshire on a sound scientific basis. Numerous species of Jurassic plants from the Yorkshire coast were figured and described in the "Fossil Flora of Great Britain," by Lindley and Hutton, which appeared in parts between 1831 and 1837. Important additions have been made to the knowledge of Yorkshire Jurassic plants by W. C. Williamson, Bunbury, Leckenby, Carruthers, Nathorst, and other writers.

Geological.—The East Yorkshire rocks of Lower Oolitic age may be said to consist of three important estuarine series, separated from one another by thin bands containing marine fossils. The majority of the plants have been obtained from the Lower Estuarine Series, which includes the famous plant-bed of Gristhorpe Bay.

Botanical.—I, Equisetales: *Equisetites columnaris* is one of the commonest and most characteristic plants of the Yorkshire flora. II, Filices: the Ferns are represented by numerous species, including examples referred to the Cyatheaceæ, Osmundaceæ, Schizæaceæ, Dipteridinæ, and Matonineæ. III, Ginkgoales: the genera *Ginkgo* and *Baiera* are both represented by several forms. IV, Cycadales: *Williamsonia*, *Nilssonia*, and *Otozamites* are the most conspicuous examples of this dominant class. V, Coniferæ: the conifers are less abundant than either the Cycads or Ferns, but the Araucarieæ appear to have occupied a prominent position in the vegetation.

The author next gives an account of the composition of the Yorkshire Jurassic vegetation as compared with that of the floras of the same geological age in other parts of the world, and makes suggestions for future work.

III.—Exhibition of a Remarkable Form of Sodalite from Rajputana. By T. H. Holland, F.R.S.

NEARLY every discovery in the interesting family of nepheline syenites shows some feature of unusual interest amongst igneous rocks. The latest discovered occurrence of these rocks in India is remarkable for the presence of a form of sodalite which has the property, apparently unique amongst minerals, of rapidly changing colour in bright daylight from carmine to pale grey or colourless, and of slowly recovering its carmine colour when kept in the dark. The mineral with these peculiar properties was discovered by Mr. E. Vredenburg as a constituent of the pegmatitic veins in a nepheline syenite intruded into the Aravalli schist series of Kishengarh in Rajputana. Along the same belt the sodalite, intergrown with nepheline in the pegmatite veins, is of the common blue variety, and nothing unusual is shown by chemical analysis of either variety. The carmine colour disappears as rapidly on exposure to light in a moist atmosphere as in dry air, in the cold weather as rapidly as at higher temperatures, and under bright electric light as in daylight. The mineral has apparently no effect on a photographic plate, and is not noticeably radio-active. The reappearance of the carmine tint takes place in a few weeks in some specimens, but requires some months' concealment in the dark in others. No explanation has been offered so far to account for this remarkable phenomenon, and the specimens are now exhibited with the hope of obtaining suggestions for a systematic investigation of the mineral.

IV.—On the Origin of the Trias. By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

THE three subdivisions of the Bunter, whether east or west of the Pennine Range, apparently unite to the south of it, and thin out as they approach the southern parts of Warwickshire, Staffordshire, and Leicestershire. Their equivalents are fairly well developed in Devonshire, but apparently thin out in a similar wedge-like manner towards the north and north-east, not reaching the Bristol Channel. The upper and lower members in the northern area are sandstones, generally red, often conspicuously current-bedded, but without pebbles, the grains being frequently wind-worn. The pebble-bed reaches a thickness of 1,000 feet near Liverpool—where, however, sand dominates over pebbles—is about 300 feet thick in the northern part of Staffordshire, and rather overlaps the Lower Bunter sand. The writer describes the lithological characters of the pebbles, and discusses the reasons for and against deriving them either from a southern or south-western source, like those in the Devon area, or from any region, either exposed or buried, in their more immediate neighbourhood, maintaining a northern origin to be the more probable. The Keuper group, both sandstones and marls, extended without interruption (except for the sea) from Devonshire to Yorkshire on the one hand, and Antrim on the other.

The author considers the Bunter to be fluviatile rather than lacustrine deposits, chiefly formed by large rivers. Two of these flowed from a mountain region, of which Scotland and the extreme north of Ireland are fragments, and a third from a similar region to the south-west of Britain. Deposits comparable with the Bunter, and especially the pebble-bed, may be found on the border of the Alps, and these rivers probably traversed (at any rate, early and late in the Bunter epoch) arid lowlands, from which, if not absorbed, they may have escaped by some channel now buried under south-eastern England. The Keuper sandstones, as he shows, indicate the setting in of inland sea conditions, the Red Marls being generally regarded as deposited in a great salt lake. These, like the clays of the Jurassic system, were probably derived from the mountain ranges, which had previously supplied sand and pebbles.

In fact, the physical and climatal conditions of the Trias—and the same perhaps may also be said of the Permian—were probably to some extent comparable with those now existing in certain of the more central parts of Asia, such as Persia or Turkestan.

V.—Notes on the Speeton Ammonites. By C. G. Danford.

A RESIDENCE of several years in the neighbourhood of Speeton has enabled the author to collect many fossils from the clays and shales underlying the Chalk. With regard to the Ammonitidæ, his results confirm the general succession given by Pavlow and Lamplugh, and add some further information.

The lowest portion of the Kimmeridge Clay which the author has been able to examine in exposures on the shore contains numbers of ill-preserved ammonites of the square-backed *Hoplites* group; while the higher part contains forms of a different type, belonging to the round-backed *Perisphinctes* and allied genera.

In the lower part of the zone of *Belemnites lateralis* Ammonites are extremely rare, and the author has no fresh information to offer; but in the upper part they become plentiful. The very globose forms of *Olcostephanus* (*O. gravesiformis*, *Keyserlingi*, etc.) occur mainly in the bed D 3 of Mr. Lamplugh's classification, but are usually in bad preservation. The overlying bed, D 2, is perhaps the most interesting of the whole series; at its base both the *Olcostephani* and the *Hoplites* are very numerous, the former being often in the condition of imperfect phosphatic casts. Above this band the round-backed Ammonites entirely disappear, though *Belemnites lateralis* continues to be fairly abundant up to D 1.

It therefore appears that the southern *Hoplites* obtained full possession of the area earlier than their associated southern Belemnites of the *jaculum* type, although rare examples of these Belemnites occur in the clays below D 2.

The lower part of the zone of *Belemnites jaculum*, besides yielding many *Hoplites*, contains occasional Ammonites pertaining to the genera *Holcodiscus* and *Astieria* (of the *Olcostephani*), and also to other genera. The higher beds are occupied by *Olcostephani* of the

genus *Simbirskites*, but these beds have of late years been so poorly exposed that no further information can be given regarding the distribution of these forms.

In the zone of *Belemnites brunsvicensis* Ammonites only occur at the extreme base, where there are a few examples of one of the *Simbirskites*, and in its uppermost beds, where the genus *Hoplites*, represented by *H. Deshayesi*, reappears associated with forms of the genus *Oppelia*, the whole of the intervening deposits being apparently devoid of these fossils.

In the beds with *Belemnites Ewaldi*, which may prove to be a distinct zone between the *brunsvicensis* and *minimus* zones, no Ammonites have as yet been detected, but in the *minimus* zone *H. interruptus*, Brug., has been found.

The Criocerata have been found to exist in most, if not all, the deposits from the uppermost part of the *Belemnites lateralis* zone to the top of the *Belemnites brunsvicensis* zone, and are especially numerous about the middle of the *Belemnites jaculum* zone. They are, however, difficult to determine, being both fragmentary and ill-preserved.

The paper concludes with a list of the species of *Crioceras*, including those described in "Argiles de Speeton" and those met with by the author, and determined chiefly by Dr. A. von Koenen. This short list might, doubtless, be greatly extended by anyone conversant with the forms of this group.

VI.—Notes on the Glaciation of the Usk and Wye Valleys.

By the Rev. W. Lower Carter, M.A.

DURING a recent holiday the author was able to study the glacial deposits of the district to the north of the South Wales Coalfield. The gravelly deposits of Old Red Sandstone material which are characteristic of the valley of the Usk between Brecon and Abergavenny (see "Geological Survey Memoir") have been traced for some distance to the north-east of Brecon and up the valley of the Usk as far as Trecastle. Here the river breaks away from the old 'through' valley, which is continuous to Llandovery and rises in the Carmarthen Fans to the south. On the top of this red drift were found large numbers of erratics of volcanic ash and breccia, which the author supposes to have been derived from Ordovician outcrops to the west or north-west of the area in question. These blocks, which run up to two tons or more in weight, are found all down the Usk Valley below Trecastle, and over the col towards Llandovery, in the Gwyddrig Valley, as far down as 'Halfway.' The author has traced them on the flanks of the Brecon Beacon as high as Newadd (886 feet) and down to Talybont, where a large one was found close to the canal tunnel (400 feet). At Llangorse they form part of a moraine which dams back the drainage to form Llangorse Lake. They are found in large numbers at Talgarth, and were

traced up Cwm Pwll-y-wrach as high as the 800 foot contour. Numbers of smaller boulders were found mixed with Old Red Sandstone material in gravel deposits near Three Cocks Junction, a little stream revealing good sections in mounds of rearranged and roughly bedded drift deposits. No trace of these foreigners was found in the valley of the Wye from Builth Wells to Three Cocks, nor were any found in fine sections of Boulder-clay examined at Llandrindod Wells.

The author hopes to continue the investigation of these deposits, but believes that sufficient evidence has been collected to point to a local glacier at first in each of the valleys of the Usk and the Wye. The Usk glacier was fed from the Carmarthen and Brecon Fans, but appears to have been overridden subsequently by a stream of foreign ice from the direction of Llandovery, bringing the brecciated erratics and pressing down the valley to Llangorse, Talgarth, and Three Cocks. It is to the pressure of this foreign ice that he would attribute the overflow of the Old Red Sandstone drift by the Cray Valley, on to the Carboniferous rocks of Penwyllt, and up Dyffryn Crawnon and through the faulted gap of Nant Trefil into the Rhymney and Sirhowy valleys (as reported by the Geological Survey). Among the erratics of the Wye Valley were tough green grits, which were subsequently found quarried at Builth, but marked on the geological map as 'Greenstone.' Several interesting stream diversions, owing to accumulations of morainic material, were observed. Amongst the more important were the diversion of the Usk from a wide valley to a narrow gorge at Aberyscir by a moraine at Cradog; of the Honddu at 'The Forge,' Brecon, to the glacial gorge which runs below the Priory Church; and the reversal of the drainage of the Afon Honddu and Olchon Brook at Llanvihangel and Pandy by the morainic gravels which block the wide valley between Bryn-aro and Skirrid-fawr, down which these streams no doubt flowed in pre-Glacial times to join the Usk at Abergavenny, whereas now they have been diverted into the Monnow, and so reach the Wye at Monmouth.

Only one case of a dry valley which had been a glacier-lake overflow was noted, and that was the little gorge called Cwm Coed-y-cerig, by which the drainage of Orwyne Fawr appears to have been carried off when the lower part of its present valley was obstructed by a lobe of ice from Crickhowell, but it was not cut deeply enough to continue to take the stream when the lobe was withdrawn.

REVIEWS.

I.—Smithsonian Institution: United States National Museum.

I. The United States National Museum: an Account of the Buildings occupied by the National Collections. By Richard Rathburn, Assistant Secretary of the Smithsonian Institution.

(Report of the U.S. Nat. Mus. for 1903, No. 132, pp. 177–309, with 29 plates; 8vo, Washington, 1905.)

II. Studies of the Museums and Kindred Institutions of New York City, Albany, Buffalo, and Chicago, with Notes on some European Institutions. By A. B. Meyer, Director of the Royal Zoological, Anthropological, and Ethnographical Museum in Dresden. (Report of the U.S. Nat. Mus. for 1903, No. 133, pp. 311–608, with 40 plates; 8vo, Washington, 1905.)

1.—Professor Huxley defined a museum as "a consultative library of objects." The National Museum is much more than this, for besides being a museum wherein natural history specimens are stored, it is also a distributing agency for the instruction of the people of the whole country, not only for institutions occupied exclusively with science, but also for those in which science is taught as an accessory to other branches of study. Duplicate sets of specimens are accordingly distributed, accurately named, and given to public institutions in all parts of the country.

The history of the museum may be divided into three periods; first, from its foundation in 1846 to 1857, during which time the chief object was scientific research by means of the materials gathered; second, from 1857 to 1876 the establishment became a receptacle for scientific material which had already been studied, a portion of it being exhibited to the public and thus made subservient to education; the third period witnessed the further development of the educational purpose of the museum by providing students of all countries with the means of pursuing their researches within its walls. These three functions are indeed essential to the life and progress of every museum, and they are promoted to a remarkable extent by the National Museum at Washington.

In order to meet the growing demands of the establishment and to relieve the congested state of the storage space in the old building, it was resolved in 1903 to erect a new one fully equipped with all the most recent appliances. This building will be rectangular in shape and faced with granite on all sides. It will have a length of 550 feet, a width of 318 feet, and a height above the basement floor of 77 feet. The exhibition space will occupy the two middle stories, the others being devoted to the many necessities of a large museum. The net floor area will be about 411,374 square feet, or about 9·44 acres.

The last twelve pages of the report contain a detailed statement of the space occupied by the museum on January 1st, 1904, arranged mainly in explanation of the plan of the two principal existing buildings.

2.—This very full and interesting description of Museums and Libraries is a translation of the original memoir published in Dresden 1900–1903. The author was commissioned by the authorities of the Royal Collections to undertake the work, and he appears to have accomplished his task with great efficiency. He considered that the libraries in the United States had in general

attained a higher degree of development than the museums, and that they perhaps excel those of Europe in structural details and in administrative methods, but that this is not so decidedly the case with the museums. The opinion of the late Dr. von Zittel, of Munich, is cited to the effect that the Americans had begun (1883) to make their natural history treasures accessible to the public and to specialists in a manner worthy of admiration and of imitation. Again, Alfred Russel Wallace (1887) considered that the Museum of Comparative Zoology of Harvard University (known as the Agassiz Museum) far excelled all European museums as an educational institution for the public, for students, and for the special investigator. The author was much impressed with the administrative capacity of the Americans, and considered that museum affairs on the whole stood on a higher plane than in Europe. This view refers rather to scientific than to art institutions.

A few figures will best illustrate the development of libraries and museums in the United States as compared with Germany, France, and England. There are in the United States 8,000 public libraries, containing 50,000,000 volumes. The increase in the number of museums does not keep pace with these amazing results, although it has often been recommended that a small popular museum should be attached to each public library. There are 350 public museums, of which 250 are devoted to natural history. Germany has perhaps 500 or more, 150 of which are natural history museums. France has 300 of the latter, and Great Britain 250. A remarkable feature in some of the large American museums is a section specially adapted to the comprehension of children, and this is supplied also in nearly all of the large libraries. The object is to develop the minds of children and to inspire them with a love for nature. This idea had long ago been suggested by Louis Agassiz.

This voluminous paper is admirably illustrated with pictures of many of the museums and libraries visited by the author.

A. H. F.

II.—The Species of *Botryocrinus*. By F. A. Bather. Ottawa Naturalist, vol. xx, pp. 93–104; August 15, 1906.

THIS paper contains a comparison of all previously described species, with fresh diagnoses based on the dorsal cups. The species are:—Swedish, *B. ramosissimus*, Ang., *B. cucurbitaceus* (Ang.); British, *B. ramosus*, Bather, *B. decadactylus*, Bather ex Salter MS., *B. pinnulatus*, Bather, *B. quinquelobus*, Bather; Australian, *B. longibrachiatus*, Chapman; North American, *B. nucleus* (Hall), *B. polyxo* (Hall), *B. crassus* (Whiteaves), *B. americanus*, Rowley. All these are Silurian except the last two, which are Devonian and approach the Carboniferous *Barycrinus* in shape. American workers are invited to consider the relations of *Botryocrinus* to *Cosmocrinus*, *Barycrinus*, and *Vasocrinus*.

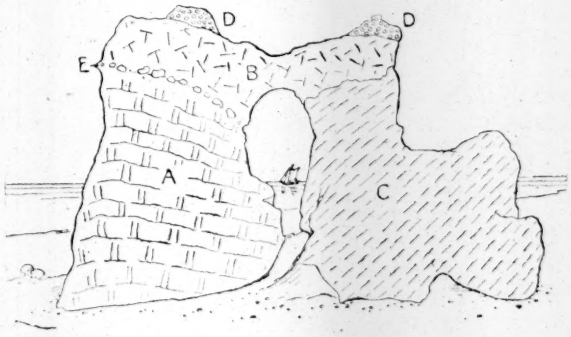
The Chalk Arch at Trimmingham, Norfolk, as seen in July, 1906.

CORRESPONDENCE.

TRIMMINGHAM CHALK BLUFFS.

(PLATE XXVII.)

Sir,—You may be interested to know that I spent a short fortnight in East Anglia. *Apropos* of Trimmingham I endeavoured to identify Mr. Brydone's photographs. He appears to have taken no notice of the extraordinary natural arch situated a few yards from the base of the cliff, a miniature 'Old Harry.' Enclosed is a rough sketch of this peculiar specimen of the Contorted Drift, which owes its preservation, in a great measure, to an intensely hard bed of flint pebbles (D). There are two fragments of this remaining, and during my visit two young Philistines were doing their best to destroy the one on the left hand. I preached them an appropriate sermon on the folly of destroying interesting natural objects, and they had the good sense to desist. I also send you photograph taken by Messrs. Tucker showing the natural arch as seen by me in July last (see Plate XXVII).

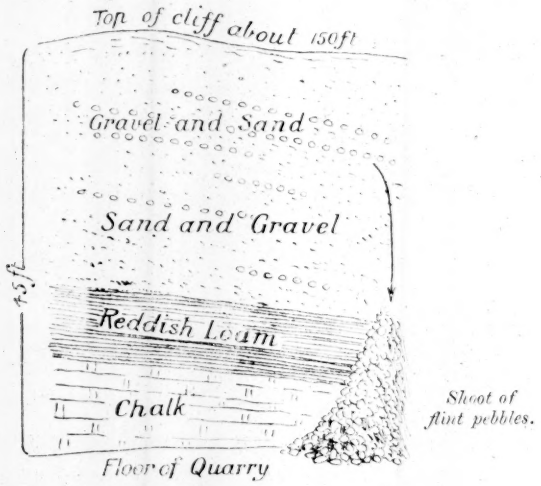


Natural arch on the sea-shore at Trimmingham.

A. Chalk *in sitû* unaltered and full of flints.
B. Modified Chalk with much impurity.
C. Pugged grey clay with some stones.
D. Conglomerate of flint pebbles.
E. The principal flint band.

This mass of marly Chalk in the Trimmingham cliff is situated just below the Crown and Anchor Hotel, the 'marl' being burnt for lime (July 31st, 1906). It is evidently a mass of squeezed and softened Chalk, but I did not notice flints in it. A quantity of flint pebbles, some very large, are obtained from the overlying gravels for road-mending, etc. There are several smaller lumps of softened

Chalk in the cliff hereabouts, and the cliff itself is much fissured and crevassed. The beds dip towards the north-east (approximately).



The elevation of the church at Trimmingham is marked in the old map as 195 feet, and the top of the cliff here is from 40 to 50 feet lower. W. H. HUDLESTON.

NOTE.—The mass of Chalk forming the arch (see Pl. XXVII) was only entirely isolated and detached from the adjoining cliff early in this year. (See Mr. Brydone's Plates, GEOL. MAG., 1906, Pl. II, Figs. 2, 3; Pl. IV, Fig. 7; Pl. V, Fig. 12; Pl. VIII, Fig. 13. See also description by Prof. Bonney in Sept. No., pp. 400-403, Fig. 1, A, and Fig. 2.)—EDIT. GEOL. MAG.

THE THICKNESS OF THE CIRCUM-POLAR ICE.

SIR,—Your reviewer of the first volume of Professors Chamberlin and Salisbury's Geology has the following sentence on p. 376: "We note that the thickness of the Greenland ice-dome at its centre is estimated at 5,000 feet or more, and we recommend the statement to the attention of the writer in this Magazine (March, 1906, p. 120) who has recently, on hypothetical grounds, revived the idea that ice cannot attain a greater thickness than 1,600 feet." May I again point out that the 5,000 feet ice-sheet is a pure assumption, whereas the 1,600 feet limit rests on physical experiment and direct field observation? Professors Chamberlin and Salisbury's statement, which your reviewer refers to with such satisfaction, is as follows: "The height of the land surface beneath [the ice-cap] is unknown, but it is unlikely that it averages half this amount [9,000 feet], and hence the ice is probably 5,000 feet or more thick in the centre. There is reason to think it is much thicker in Antarctica." This is simply an appeal to ignorance; and as regards the Antarctic, Captain Scott's observation

that evaporation equals precipitation on the plateau leads one to infer that it is likely that the ice-cap there is quite thin. If the upholders of the 5,000 feet ice-sheet will produce the record of a tabular iceberg more than 1,600 feet thick, or if they will show that there is a valley 5,000 feet from crest to trough running under the flat ice-cap of Greenland—the observations at present available tending to show, on the contrary, that the deep valleys on the coast go but a short way inland and end abruptly on the edge of a plateau —then I will believe that physical laws have been suspended in their operation for the special benefit of glacialists.

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THE TRIMMINGHAM CHALK.

Sir,—It seems desirable to make a few comments on Professor Bonney's paper in your September number. On the question of "western and eastern" or "northern and southern" bluffs, I cannot see what the trend of the coast, ever varying from point to point and as you take it at the base or top of the cliff, can have to do with the relative position of two fixed points. A line drawn from bluff to bluff runs by the compass 5°–10° S. of S.E., so that I and any earlier writers who used *magnetic* bearings are accurate in speaking of "northern and southern" bluffs. Can it be that Professor Bonney is treating our magnetic bearings as if they were geographical, and supplying an instance of the very confusion I sought to forestall by a note obviously addressed to the general public. (Professor Bonney affects to regard it as addressed to him personally, but I can assure him that the paper by him and Mr. Hill gave rise to no alteration in the form or substance of mine.) On the East Coast it is in any case natural (and not inaccurate) to speak of points along the coastline as north and south, while they are no nearer due east and west than 10°–15° E. of S.E indicates.

I am less fortunate than Professor Bonney in having only found one place where the foreshore chalk has a skin of boulder-clay, the plastic clay having, under pressure from the cliffs above, crept over the chalk for a few yards in a depression. It seems a very natural thing to happen.

Professor Bonney has not fully grasped my theory as to his blocks A, C, and E. I believe that the eroded surface, unconformable to the lines of flint, of the *Ostrea lunata* chalk in these three blocks was formed in Cretaceous times, and then still in Cretaceous times the grey chalk was deposited on it, most thickly in the hollows, e.g. between C and E, and in the pocket in the seaward face of A shown by my figs. 13 and 16. On this theory no twisting of the grey chalk is required, nor is there any difficulty in its occurring still at the top and bottom of the sloping face of C. (As I have stated, it formerly covered the whole of this sloping face and was continuous *above* the sand with the grey chalk in E.)